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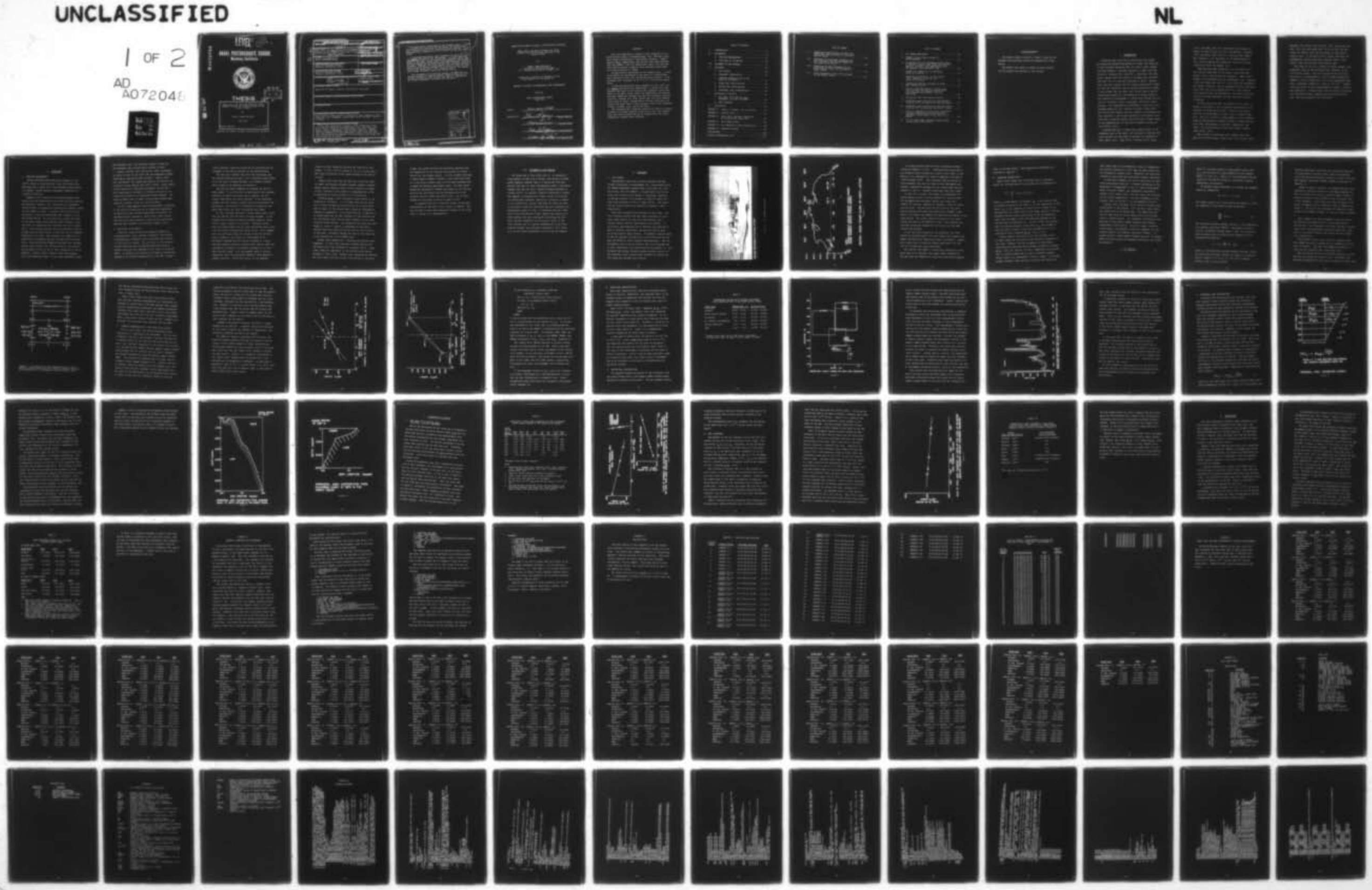

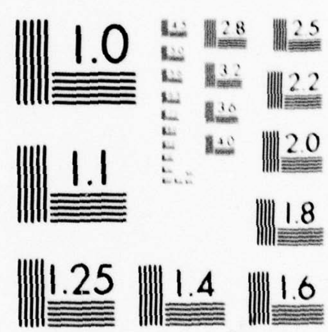

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THESIS

MASS, SALT, AND HEAT TRANSPORT BY OCEAN CURRENTS ACROSS 35° NORTH LATITUDE IN THE PACIFIC OCEAN

by

Dennis James Whitford

June 1979

Thesis Advisor: G. H. Jung

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This work represents a synoptic study conducted in the North Pacific Ocean to determine mass, salt, and heat transports from a calculation of geostrophic currents. Comprehensive depth, temperature, and salinity data were obtained from the INDOPAC I and XVI expeditions (April 1976 and July 1977) which covered a complete cross-sectional area along 35°N from California to Japan.

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The geostrophic approximation was assumed valid. A level of no motion was determined at 851 meters by establishing mass continuity across the latitudinal cross section. A net northward salt transport of 16.27 x 10^{12} o/oo/sec was determined.

10 to the 12th power

A resulting meridional heat transport of 288 x 10^{12} cal/sec toward the equator was determined. It would have been expected that most of the oceanic heat transport would take place in the upper waters where the temperature and currents are much higher and stronger and that the transport would be poleward. However this study showed that the lower temperatures found at depth, transported at slower velocities, can balance the upper waters' heat transport due to the tremendous volume of middle, deep, and bottom water.

The southward heat transport agrees with previous research estimates by several authors using earlier and less synoptic data with other methods and may be compensation for excess atmospheric poleward heat transport.

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Mass, Salt, and Heat Transport by Ocean Currents Across 35° North Latitude in the Pacific Ocean

by

Dennis James Whitford
Lieutenant, United States Navy
B.S., United States Naval Academy, 1972

Submitted in partial fulfillment of the requirements for the degree of

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This work represents a synoptic study conducted in the North Pacific Ocean to determine mass, salt, and heat transports from a calculation of geostrophic currents. Comprehensive depth, temperature, and salinity data were obtained from the INDOPAC I and XVI expeditions (April 1976 and July 1977) which covered a complete cross-sectional area along 35°N from California to Japan.

The geostrophic approximation was assumed valid. A level of no motion was determined at 851 meters by establishing mass continuity across the latitudinal cross section. A net northward salt transport of 16.27×10^{12} $^{o}/oo$/sec was determined.

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The southward heat transport agrees with previous research estimates by several authors using earlier and less synoptic data with other methods and may be compensation for excess atmospheric poleward heat transport.

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ACKNOWLEDGEMENTS

The author wishes to thank Dr. Glenn H. Jung for his guidance and assistance during the preparation of this thesis.

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I. INTRODUCTION

Scientists have theorized on the earth's heat budget and resulting transporting mediums for almost two centuries. It had long been recognized that the earth's polar regions lose more energy by long-wave radiation to space than they receive by incoming solar radiation. Conversely, the equatorial regions gain more energy by incoming solar radiation than they lose via long-wave radiation to space. However, since the polar regions have not become progressively colder, nor have the equatorial regions become progressively warmer, it was assumed that the excess heat in the tropics must be transported poleward by some mechanism of energy transfer. The conduction of geothermal or oceanic heat through the sea floor is relatively small; consequently the earth's fluid envelope - the atmosphere and hydrosphere - must act as the exchange medium for this transfer of energy (Jung, 1955). The problem then became, and still remains, to determine how this transport is partitioned between (a) the fluxes of sensible heat, potential energy, and latent heat of water vapor in the atmosphere and (b) the flux of energy in ocean currents (Bryan, 1962).

Although much more is known about energy fluxes in the atmosphere than in the ocean, the existence of warm and cold ocean currents has been known to mariners for hundreds of years (Emig, 1967). Jung (1952), Sverdrup (1957), Bryan

(1962), and Emig (1967) have shown that the transport of energy by ocean currents is quite considerable. Sverdrup (1957) and Bryan (1962) went on to indicate that oceanic heat transport is of importance to the meteorologist as well, thus portending the present day studies of air-sea interaction (Perry and Walker, 1977).

There has been much controversy over the years as to the relative importance of the ocean's versus the atmosphere's role in meridional heat transport. Maury (1856) thought the hydrosphere held the predominant role. Angstrom (1925) and Vonder Haar and Oort (1973) found the atmospheric and oceanic transports were of comparable overall importance. Jung (1955) felt that although the role of the ocean was less important than the atmosphere's, the ocean's contribution was far from negligible and thus should be seriously considered.

In 1952, Jung proved that the transfer of all forms of energy in the ocean is very accurately approximated by the transfer of thermal energy alone. There are two methods used for the measurement of oceanic heat or thermal transport. The first consists of measurements of heat transport based on calculations of dynamic heights to obtain velocity from direct measurements of salinity, temperature, and depth. The second method utilizes heat balance computations (Bryan, 1962).

Many studies of meridional heat transport have been done in the North Atlantic Ocean (Jung, 1955; Budyko, 1956;

Sverdrup, 1957; Bryan, 1962; Sellers, 1965; Vonder Haar and Oort, 1973; Oort and Vonder Haar, 1976) but only the most recent one (Baker, 1978) had the fortune to have nearly synoptic data. In the North Pacific Ocean, relatively few comprehensive studies have been conducted (Bryan, 1962; Wyrtki, 1965) and none have used synoptic data.

This study is the first synoptic or nearly synoptic comprehensive study of the meridional heat transport in the North Pacific Ocean. Data were obtained from the Scripps Institution of Oceanography by the R/V Thomas Washington's INDOPAC I cruise in March/April 1976 with supplemental data from a subsequent INDOPAC XVI cruise in July 1977. Computations were based on direct measurements of depths, salinity, and temperature. Dynamic heights and the level of no motion were calculated using a computer and resulting net mass, salt, and heat transports were determined.

II. BACKGROUND

A. PREVIOUS MEASUREMENTS

Present knowledge concerning heat transport in the world's ocean is relatively poor since few studies have been made and of those, most were performed using dissimilar methods, thereby making a meaningful comparison of transports difficult.

Houghton (1954) studied the Northern Hemisphere heat balance and used observational data from the North American pyrheliometric network. His calculations of atmospheric radiation made no assumptions regarding the planetary albedo nor the albedo of clouds. Sverdrup (1957) was the first researcher to calculate meridional heat transport by the heat budget method. He calculated heat sources and sinks at the ocean surface using radiation data (Kimball, 1928) and charts of evaporation and turbulent heat flux (Jacobs, 1951). Heat storage problems were not considered since he assumed that the heat content of the ocean was not changing appreciably with time. Heat transport was computed by integrating its divergence between latitude belts as boundaries. Both Sverdrup and Houghton concluded that the mean oceanic heat transport for the North Pacific was poleward and estimated to only be 10% of that transported by the atmosphere. Several authors (Manabe, 1969; Bryan et al., 1975) used numerical models of the ocean-atmosphere system

and concluded that a net poleward transfer of heat was more probable than an equatorward transfer of heat.

However, Patullo (1957) and Wyrtki (1965) calculated an influx of heat to the ocean from the atmosphere thereby inferring an equatorward heat transfer. Tabata (1965) also calculated a net annual heat gain as far north as 50° latitude at Ocean Station Papa (50°N, 145°W). Bryan (1962), using a method for combining hydrographic station data and climatological estimates of surface wind stress, concluded the presence of an equatorward heat transport. He used the NORPAC data of August 1955 and heat balance maps compiled by Budyko (1956) and Albrecht (1960).

In 1952, Jung suggested that the meridional circulation in the vertical plane could be of significant importance, in addition to the horizontal meridional circulation, in determining heat transports. Bryan (1962) later stated that the slower mean currents in the vertical plane could dominate heat transport in the oceans (Tabata, 1975).

B. THE LEVEL OF NO MOTION

Since this study utilized the dynamical method for calculating mass, salt, and heat transports, the problem of determining a reference level along which the velocity is zero had to be solved. This was done so that absolute current velocities may be determined when the relative current velocities are referred to this level of no motion (LNM). In essence, the reliability of dynamic calculations depends on an accurate determination of the LNM. Greeson

(1974) provided a detailed discussion of the historical development of the various methods of LNM determinations.

The four basic methods that have been postulated thus far include choosing the LNM: 1) at a sufficient great depth, 2) at the level of oxygen minimum, 3) by Defant's method, and 4) based on the equation of continuity.

The earliest method depended on choosing the LNM at a great depth. It was felt that in deep waters, the isopycnal surfaces are nearly horizontal and in general, all the oceans' deep waters are nearly uniform. It was therefore assumed that the isobaric surfaces were also horizontal and motionless. The discovery of substantial currents on the deep ocean floors has since invalidated this theory.

In 1916, Jacobsen initiated a second theory which stated that the LNM was also the level of oxygen minimum. It was assumed that biological processes consume oxygen by oxidation of organic matter at all levels. Therefore layers where the oxygen supply has not been replenished after oxidation are layers of minimum horizontal motion. This argument runs into difficulty when one considers that the distribution of oxygen in the oceans has been assumed to be stationary, meaning that the inflow of oxygen at a given time and volume by physical processes must exactly equal the consumption of oxygen by biological processes at the exact same time and volume. This requirement leads to certain conceptions about the biological community which appear extremely arbitrary. Rossby and Iselin, in two separate

studies in 1936, tended to disclaim the veracity of this method. In 1937, Dietrich showed in his Gulf Stream experiment that utilization of the oxygen minimum as the LNM was in error.

Defant (1941) felt that the LNM lies within the interval where the relative distances between isobaric surfaces remains nearly constant within certain intervals of depth. However, accuracy of this method is downgraded due to the accumulation of errors involved in its calculation.

Sverdrup _et al_. (1942) developed a method based on the equation of continuity. It is evident that the net transport of water through any cross-section in an ocean basin must be equal to zero because water cannot be continuously removed or accumulated. In the North Pacific, a LNM had to be chosen where the net mass transport in one direction below the LNM must equal the net mass transport in the other direction above the LNM. This method has not been used until recently, since it requires a comprehensive and nearly synoptic data base across an entire vertical cross-section of the ocean. Sverdrup's method was used in this study due to the availability of the INDOPAC data.

Several other methods for determining the LNM have been suggested. In 1938, Parr developed a method dealing with the distortion of the thickness of isopycnal layers. Fomin (1964) added the importance of the vertical water density gradient to Parr's work. Hidaka (1940) developed two methods. The first dealt with the salinity distribution in the water

column, the second involved the continuity equations and the computation of the vertical distribution of current velocity by the dynamic method. In 1956, Stommel developed a method based on Ekman's concept of the ocean consisting of a wind driven surface layer of frictional influence and a deeper frictionless geostrophic layer. The most recent method was developed by Stommel and Schott in 1977 and was based on the beta-spiral and the determination of the absolute velocity field from density data. All of these methods are described in detail by Baker (1978).

As suggested from this literature survey, an accurate determination of the LNM is still subject to debate. This must be kept in mind when viewing the results of any study which is based on its determination.

III. STATEMENT OF THE PROBLEM

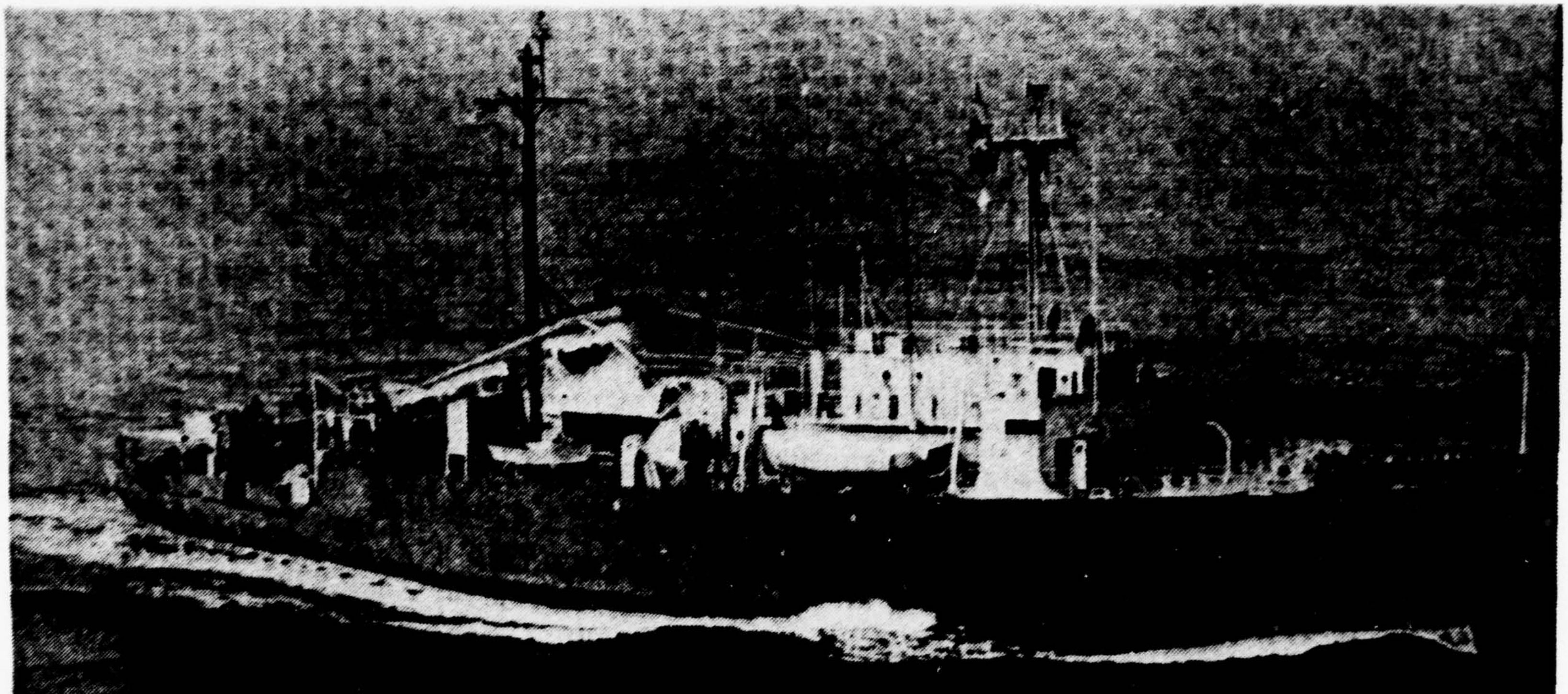
The objectives of this study were to: (1) manipulate large amounts of data from a Scripps Institution of Oceanography magnetic computer tape to a medium and form compatible with the U.S. Naval Postgraduate School's IBM 360/67 computer and with the basic computer program developed by Greeson (1974); (2) develop a computer subroutine to enable the computer to automatically select a level of no motion vice having the researcher laboriously calculate it manually; (3) establish a constant LNM along 35° North latitude in the Pacific Ocean for which mass and salt transports are approximately equal to zero; (4) determine the heat transport of the North Pacific Ocean; compare the results with other studies; and draw conclusions concerning the mass, salt, and heat transports in the various layers of the cross section; and (5) provide documentation on the basic computer program, plus additions developed in this study, so as to aid future researchers in utilizing the program.

IV. PROCEDURE

A. DATA SOURCE

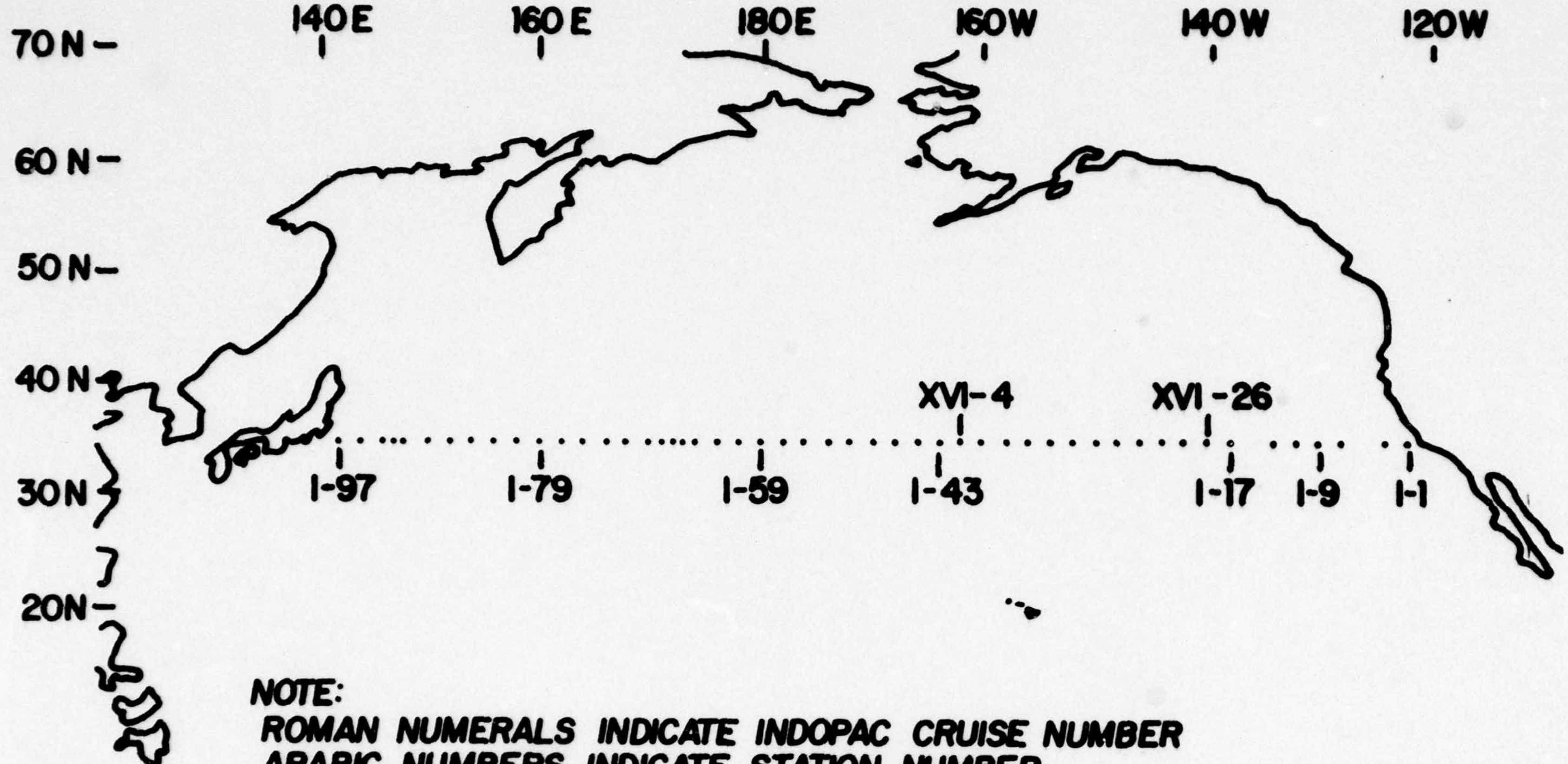
Oceanographic data were initially obtained from the Scripps Institution of Oceanography for a cruise made on the R/V THOMAS WASHINGTON between March 23 and April 30, 1976. The cruise, entitled INDOPAC I, obtained data from 98 stations (one at every whole degree of longitude), spaced at an average distance of 91 kilometers along 35° North latitude from California (122°W) to Japan (141°E). The vessel and the cruise location are depicted in Figures 1 and 2, respectively.

These data presented two problems for this study. The first problem resulted from the cruise procedure to alternate a deep station (to near the ocean bottom) with a shallow station (down to approximately 1200 meters). To avoid gross approximations and to maintain the required degree of accuracy, geostrophic calculations must be done utilizing adjacent deep stations. The deepest standard depth of the two adjacent stations must be well below the LNM and near the bottom to avoid transport approximations. Thus approximately half of the 98 stations had to be discarded due to their shallowness (see second section of Appendix C). This increased the average distance between stations from 91 to 182 kilometers with a proportional decrease in station density along the latitude cross-section.



Thomas Washington (Courtesy UCSD)

Figure 1. R/V THOMAS WASHINGTON



NOTE:
ROMAN NUMERALS INDICATE INDOPAC CRUISE NUMBER
ARABIC NUMBERS INDICATE STATION NUMBER

INDOPAC CRUISE TRANSIT ALONG 35° NORTH LATITUDE

Figure 2

The second problem resulted from a mechanical problem during the INDOPAC I cruise. A malfunctioning winch aboard the research vessel allowed only shallow casts (down to 1200 meters) to be completed for stations numbered 18 through 42 (139°W through 163°W). This continuous shallow section of 2184 kilometers was much too long to allow meaningful geostrophic computations between the two closest deep stations, numbered 17 and 43. Therefore additional data were sought.

In July 1977, Scripps Institution of Oceanography conducted another cruise, entitled INDOPAC XVI, which covered the aforementioned continuous shallow area along 35°N. INDOPAC XVI stations, numbered 26 through 4 (140°W to 162°W), were utilized. The data used for this study in the short section between 140°W and 162°W consisted of INDOPAC I data down to 1200 meters and INDOPAC XVI data from 1250 meters to the ocean bottom. The actual location utilized for this short section was that of the INDOPAC XVI data. The longitude and latitude differences between the two cruises for the same station were minimal.

It was felt that synopticity and continuity were maintained for the March/April 1976 time frame since seasonal and annual variations are found mostly above 1200 meters. Comparison of data below 1200 meters between March/April 1976 and July 1977 showed only minor deviations.

The data for the INDOPAC I cruise were received on a magnetic tape in 80 character card image format (Appendix D). The data from the INDOPAC XVI cruise were received on computer

cards in the same format. Tape manipulation procedures are contained in Appendix A.

B. TRANSPORT COMPUTATIONS

Baker (1978) showed that the energy flux or transport across any latitude barrier in the ocean can be expressed as:

$$T_o^* = \int_0 \rho_s \, C_{ps} \, T_s \, V_{ns} \, dO \, , \qquad (1)$$

where ρ_s is the density of seawater, C_{ps} is the specific heat at constant pressure of sea water, T_s is the temperature of sea water, V_{ns} is the component of fluid velocity normal to the latitude wall at a given level in the ocean, and dO is the differential vertical cross section area of the latitude wall. Jung (1955) and Baker (1978) have detailed explanations for the derivation of Equation (1). For this study, the specific heat at constant pressure of sea water, C_{ps}, was assumed to have the value of unity, since that introduced only an insignificant error (Sverdrup *et al.*, 1942, p. 62).

Actual synoptic velocities across any latitude circle of great length for any ocean are not feasible to measure at this time. However, with the assumption of geostrophic equilibrium and utilizing the procedure outlined by Sverdrup *et al.* (1942, pp. 408-411; 447-448), temperature and salinity data at standard depths may be used to determine dynamic height values, and subsequently, velocity values. For oceanographic purposes, where physical processes and forces vary

much slower than in the atmosphere, values of temperature and salinity obtained in a less than one month period can be considered as synoptic data. Therefore, the velocities obtained by this study were considered synoptic velocities.

An IBM 360/67 computer was used to facilitate the numerous calculations involved. A program originating in the Department of Oceanography of the U.S. Naval Postgraduate School, entitled "HYDRO", and subsequently modified by Greeson (1974), Mason (1978), and this study, was utilized for the actual computations. For more information on the program, refer to Section IV (C) and Appendices E and F.

Greeson (1974) and Mason (1978) discuss in detail their contributions to the program. Only the basic ideas behind the program will be discussed here. The temperature and salinity data from the various depths were first interpolated to standard depths. All subsequent calculations were done down to the deepest common standard depth between oceanographic station pairs. Values of sigma-t, specific volume anomaly, and specific volume were computed for each standard depth by the computer subroutine "SGTSVA". An average specific volume anomaly between each pair of standard depths for each station was computed according to the following equation:

$$\bar{\delta} = \frac{\delta_z + \delta_{(z+\Delta z)}}{2}, \qquad (2)$$

where $\bar{\delta}$ is the mean specific volume anomaly, and δ_z and $\delta_{z+\Delta z}$ are the specific volume anomalies at the standard depths of z and z+Δz. Density (ρ) was determined from the inverse of the specific volume at a particular salinity, temperature, and pressure.

The dynamic height difference, ΔD, between the standard depths was computed by:

$$\Delta D = \bar{\delta}\ [z - (z + \Delta z)]\ . \tag{3}$$

The dynamic height (D) of each station was found by a vertical summation of the dynamic height differences:

$$\sum_{o}^{z} \Delta D = D\ . \tag{4}$$

The horizontal distance between stations, L, was computed by the computer subroutine "DSTSTA". Geostrophic relative velocity differences between depths 1 and 2 in an area between adjacent pairs of stations were computed with the Helland-Hansen equation:

$$V_1 - V_2 = \frac{10C}{L}\,(D_A - D_B)\ , \tag{5}$$

where L is the horizontal distance between stations A and B, D_A and D_B are the dynamic heights (or depths) of stations A and B, C equals 0.5 Ω sin θ, Ω is the earth's angular velocity, and θ is the latitude.

Absolute geostrophic velocities were calculated from relative geostrophic velocities once a LNM was determined, since the absolute geostrophic velocity is zero at the LNM. The computer subroutine "GEOCUR" handles calculations of Equation (5).

Values of density, salinity, and temperature were then available at the four corners of a rectangle composed of a pair of stations and a pair of standard depths (Figure 3). Values of velocity were available at the horizontal faces of the rectangle. These values were then averaged for the entire rectangular area in numerical steps as numbered in Figure 3. The area of the rectangle was computed by multiplying the increment of depth, Δz, with the station spacing, L.

Mass transport for each rectangular area was found by multiplying the average velocity, the average density, and the area. Salt transport (salt flux) and heat transport (heat flux) were determined by multiplying the mass transport by the average salinity and average absolute temperature, respectively.

These values of mass, salt, and heat transports were then summed vertically yielding the net transports for that pair of stations. They were also summed horizontally to yield the net transports for a particular layer.

When the LNM was varied, the absolute velocities varied, and thus the transports varied in turn. Therefore, the accurate determination of the LNM was essential to this study.

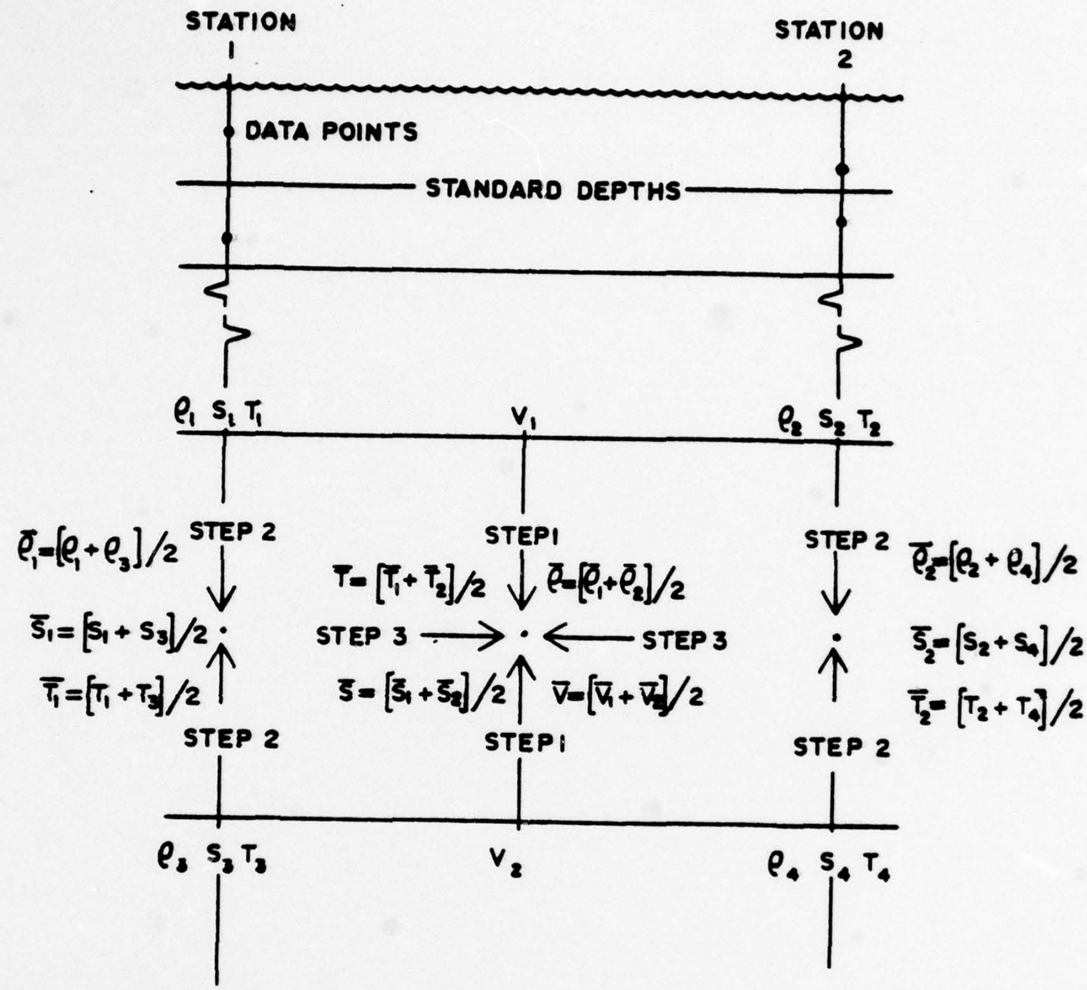


Figure 3. Illustration of the Averaging Process Used to Obtain a Central Mean Value for Velocity, Density, Salinity, and Temperature for a Rectangular Cross-Sectional Area.

The LNM was considered established when the net mass and salt transport across the entire Pacific cross section was zero, or nearly zero.

Baker (1978) stated that exact zero fluxes of both mass and salt obtained simultaneously was essentially impossible to attain due to wide data spacing, data interpolation, extrapolation techniques, and computer procedures. Therefore this study used a zero mass flux as the primary requirement with zero salt flux as a secondary requirement. When a satisfactory balance of mass and salt transport was attained, the meridional heat transport was recorded.

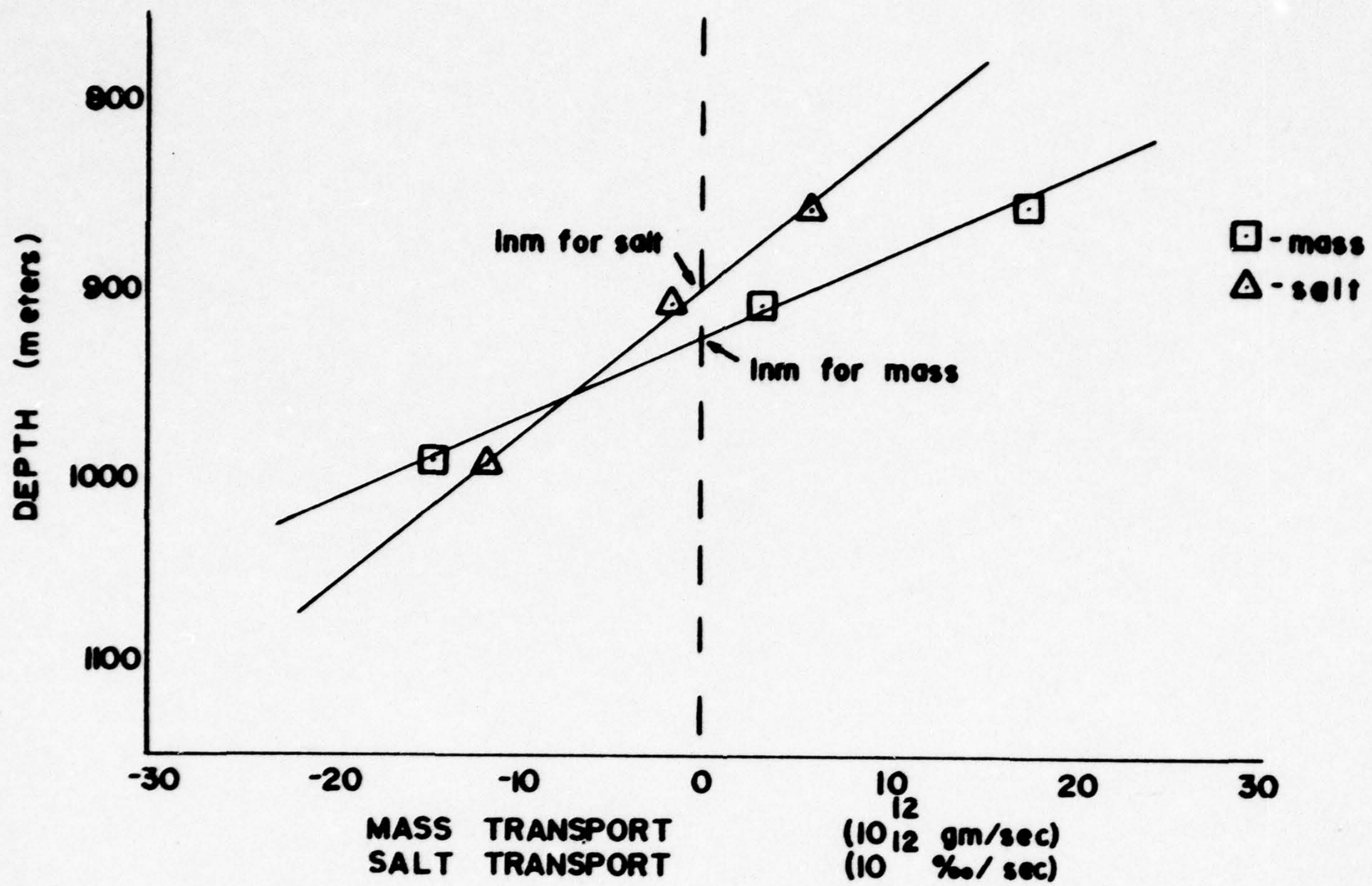
C. COMPUTER DETERMINATION OF THE LEVEL OF NO MOTION

Prior to this study, the LNM was determined rather laboriously by a man-machine mix procedure. This was done by manually setting in the program a constant LNM equal to a standard depth, for all stations and calculating the net mass, salt, and heat transports for the entire cross-section. If a selected LNM was deeper than the deepest common standard depth between the two stations (such as near a seamount), the program automatically used the deepest common standard depth. The procedure was repeated until the mass and salt transport values changed algebraic sign. Smaller intervals of standard depth were entered into the computer until the values of mass and salt transport closely approached zero. The value of the LNM entered into the program which resulted in values of mass and salt transport closest to zero was

selected as the LNM for that particular set of data. This initial procedure required a great deal of time and expense. Later, the use of a linear plot of several mass and salt transport values versus depth to determine the zero crossing depth, shortened the time required for a LNM determination. However, its accuracy still required several additional program runs near the actual LNM for accurate LNM determinations. Figure 4 shows an example where the LNM based on mass transport was 925 meters and the LNM based on salt transport was 900 meters.

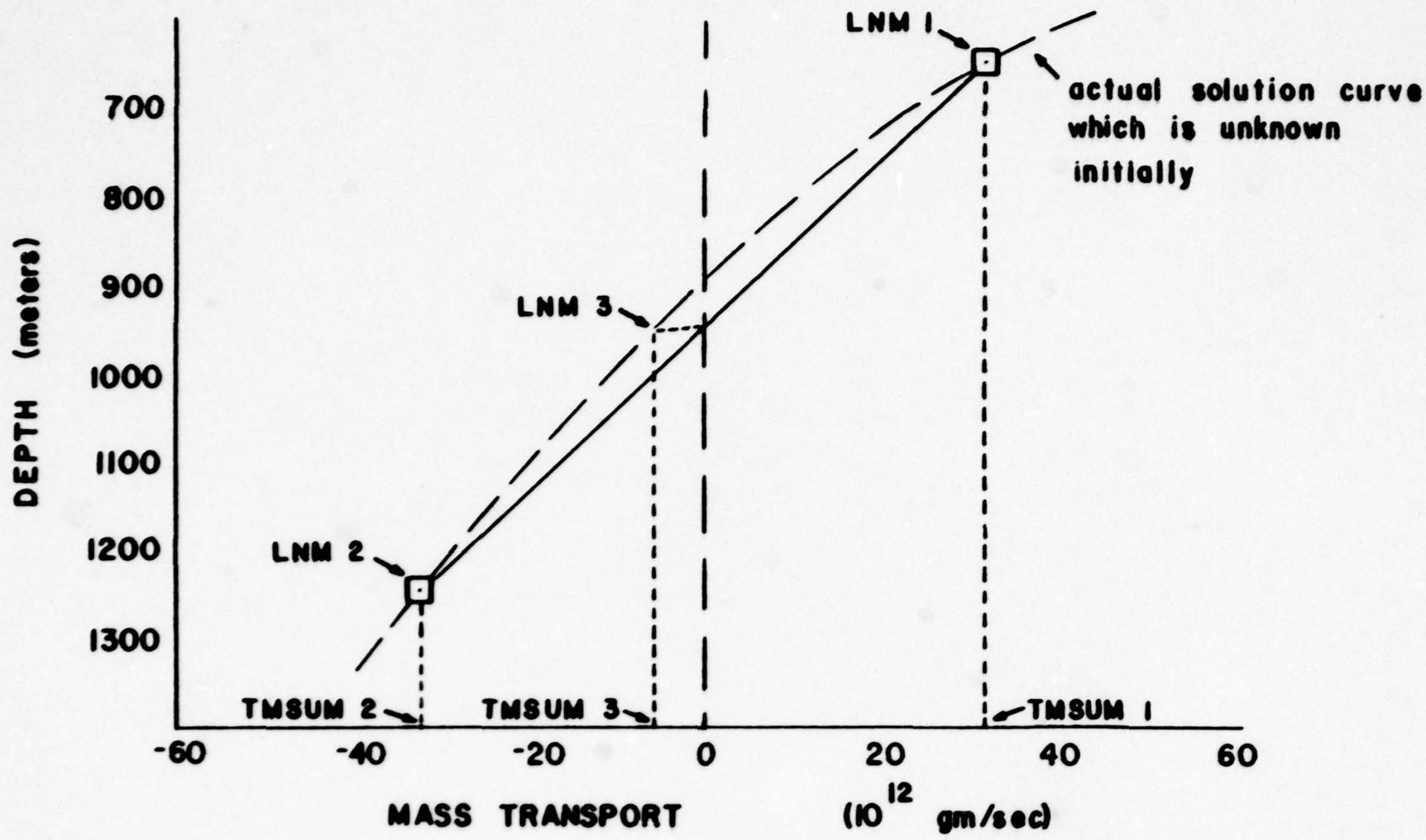
A method to accurately determine the LNM in a single program run was desired. A computer routine was developed in this study to enable the computer to automatically and accurately determine the LNM in this manner.

Two numerical analysis procedures were utilized, the bisection method (method of halving the interval) and the "regula falsi" method (method of linear interpolation). The bisection method was later discarded since it took many more iterations than the "regula falsi" method to achieve the same results. Figure 5 is a graphical illustration of the "regula falsi" method where the dashed line is the solution one is attempting to determine. An algorithm to determine a root of $f(x) = 0$, given values of x_1 and x_2 such that $f(x_1)$ and $f(x_2)$ are of opposite sign, is described by Gerald (1968) and is given below:



EXAMPLE OF LINEAR PLOT TO DETERMINE LEVEL OF NO MOTION

Figure 4



GRAPHICAL ILLUSTRATION OF THE "REGULA FALSI" METHOD TO SOLVE FOR THE LEVEL OF NO MOTION

Figure 5

```
DO while ABS(x2-x1) ≥ tolerance value and
        iterations ≤ given value
    set x3 = x1 - f(x2)[(x2-x1)/(f(x2)-f(x1))]
    IF f(x3) is of opposite sign to f(x1):
        set x2 = x3
    ELSE set x1 = x3
    ENDIF
ENDDO.
```

It must be noted that this method may give a false root if $f(x)$ is discontinuous in the interval $[x_1,x_2]$. In the program developed by this study, LNM is an abbreviation for level of no motion and TMSUM is an abbreviation for total mass transport for a given level. In addition, LNM1, LNM2, and LNM3 correspond to x_1, x_2, and x_3, and TMSUM1, TMSUM2, and TMSUM3 correspond to $f(x_1)$, $f(x_2)$, and $f(x_3)$, respectively.

The "regula falsi" method requires an initial shallow estimate and deep estimate of the LNM. These values must bracket the actual LNM to insure convergence of the routine. As an example: if an ocean area is assumed to have a LNM between 800 and 1100 meters, then choose shallow and deep estimates of 650 (LNM1) and 1250 (LNM2) meters, respectively. The program will alert the programmer if he violates this rule.

If the programmer desires to use a zero salt transport as a primary requirement for a LNM determination, a provision has been incorporated to accomplish this. Actual documentation and instructions are included in the program itself (Appendix F).

D. WATER MASS IDENTIFICATION

Water mass identification consisted of matching known values of salinity, temperature, and sometimes depth to the averaged values of temperature and salinity for each rectangular area bounded by a pair of stations and a pair of common standard depths.

Brown (1974), Williams (1962), Ingmanson _et al_. (1973), Sverdrup _et al_. (1942), and Defant (1961) were consulted for specific temperature and salinity parameters. No two authors' parameters or water masses were identical and none fit this study's data perfectly. Therefore, a composite of specific water mass parameters was determined and utilized for this study (Table I). Figure 6 is a temperature-salinity diagram for the water masses involved.

A water mass of particularly low salinity, 33.138 $^{o}/oo$ to 34.074 $^{o}/oo$, with a temperature range of 8°C to 17°C, was found near the surface off the coast of California. This low salinity water was also found by Brown (1974) in his study of the "Geostrophic Circulation off the Coast of Central California." Since it had not been previously named as a specific water mass, this study titled it CALIFORNIA due to its proximity to the State of California and the California Current.

E. BOTTOM AREA CONTRIBUTIONS

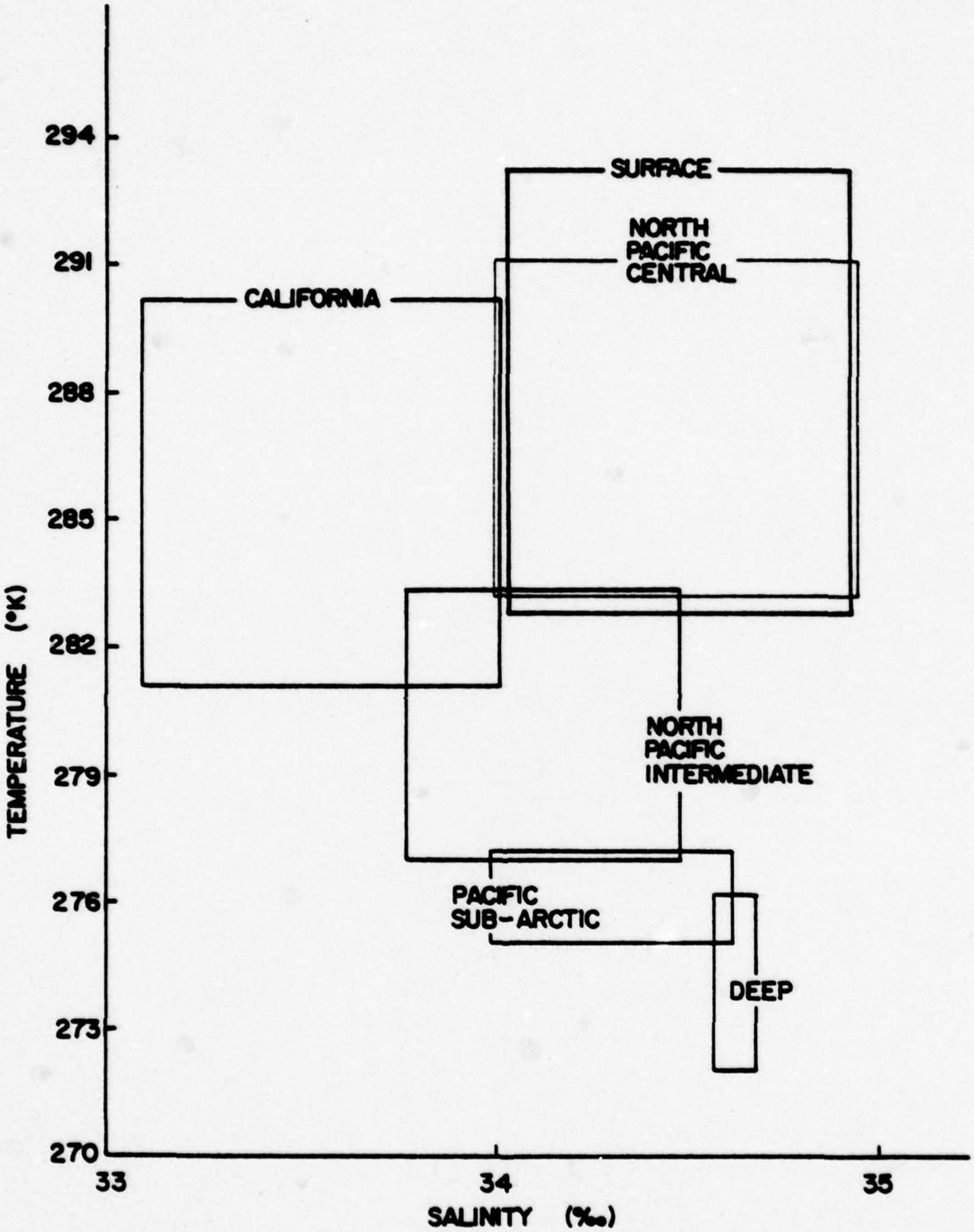
The computer program calculated all the transports from the ocean surface down to the deepest common standard depth between two adjacent station pairs. The net transport values

TABLE I

TEMPERATURE AND SALINITY CRITERIA FOR WATER MASS IDENTIFICATION IN THE NORTH PACIFIC OCEAN

WATER MASS	TEMPERATURE (°C)	SALINITY ($^o/oo$)
Surface*	10.00 - 20.00	34.075 - 34.900
North Pacific Central	10.00 - 18.00	34.050 - 34.900
California	8.00 - 17.00	33.100 - 34.074
No. Pacific Intermediate	4.00 - 10.27	33.840 - 34.500
Pacific Subarctic	2.00 - 4.00	34.000 - 34.650
Deep	-1.00 - 3.00	34.590 - 34.700

*Surface water mass had an additional requirement of being less than or equal to 150.0 meters in depth.



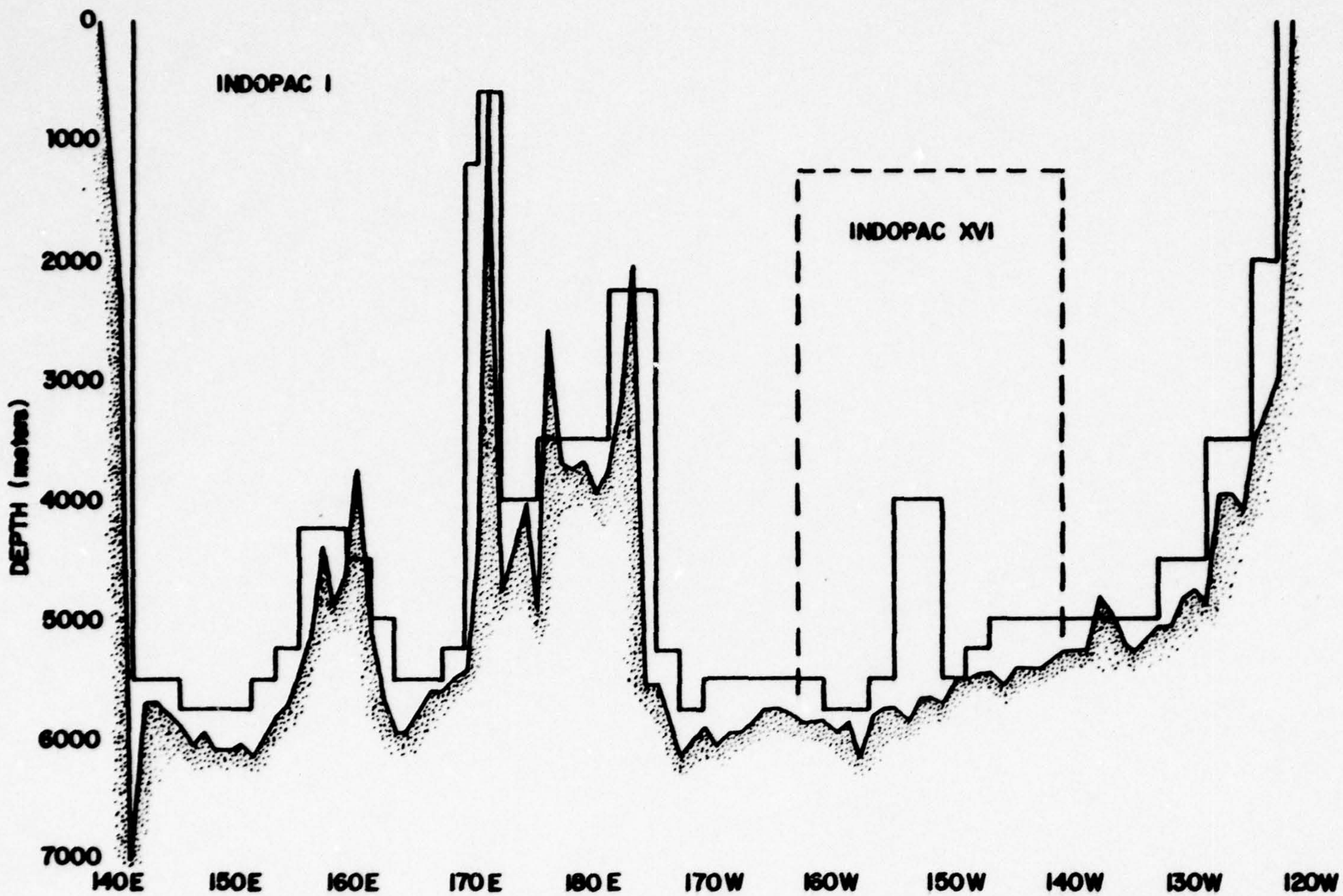
TEMPERATURE - SALINITY DIAGRAM FOR WATER MASS IDENTIFICATION

Figure 6

do not include the area between the ocean bottom and the deepest common standard depth. Therefore the bottom area contribution must be calculated and included for an accurate determination of net transports. Figure 7 depicts the bottom area as that area between the ocean bottom and the solid line.

To determine the bottom area contribution, a composite bathymetric profile was determined from the North Pacific Ocean Bathymetric Atlas (U.S. Navy Oceanographic Office, 1973) and from the depth soundings at each oceanographic station of the two cruises. The oceanographic stations were plotted with the deepest common standard depth of each station pair and the area between the ocean bottom and deepest common standard depth was obtained. Velocity was assumed to behave linearly between the geostrophic velocity at the deepest common standard depth and a value of zero velocity at the ocean bottom. Therefore, the bottom area absolute velocity was equal to one-half the deepest absolute calculated velocity. Average density, salinity, and temperature were assumed constant between the upper and lower boundary of the bottom area. Transports were then calculated as before, multiplying the bottom area by this velocity, and then by the deepest calculated density, salinity, and temperature.

These bottom area contributions were summed for the entire latitude section and then added to net transports previously calculated between the surface and the lowest common standard depth to give the total net transports of



PACIFIC OCEAN BATHYMETRIC PROFILE ALONG 35°N LATITUDE ILLUSTRATING BOTTOM AREA CONTRIBUTIONS AND INDOPAC I AND XVI DATA AREAS

Figure 7

mass, salt, and heat from the surface to the ocean bottom for the latitude section.

A significant problem can result for bottom area contributions where the lowest common standard depth between two adjacent stations is shallower than the LNM for the latitudinal cross section. An automatic provision of the program provides for the LNM to be assigned to this shallower depth. This, in turn, provides that the absolute geostrophic velocity at this point is assigned a value of zero. However, since the bottom area contribution utilizes the velocity at the lowest common standard depth to determine mass transport, it assigns a mass transport of zero to the bottom area.

If the ocean falls off rapidly in depth at this point, an extremely large bottom area contribution would be neglected. This problem occurred at the western end of the 35°N latitude section and has the potential to occur in many other latitude cross sections including shoreward transitions at latitude cross section ends and at seamounts and islands in the middle of cross sections. Appropriate steps must be taken if this occurs.

For this problem, at the western end of the 35°N latitude cross section, the shallow station was eliminated and the corresponding area was covered as a peripheral area contribution.

F. PERIPHERAL AREA CONTRIBUTIONS

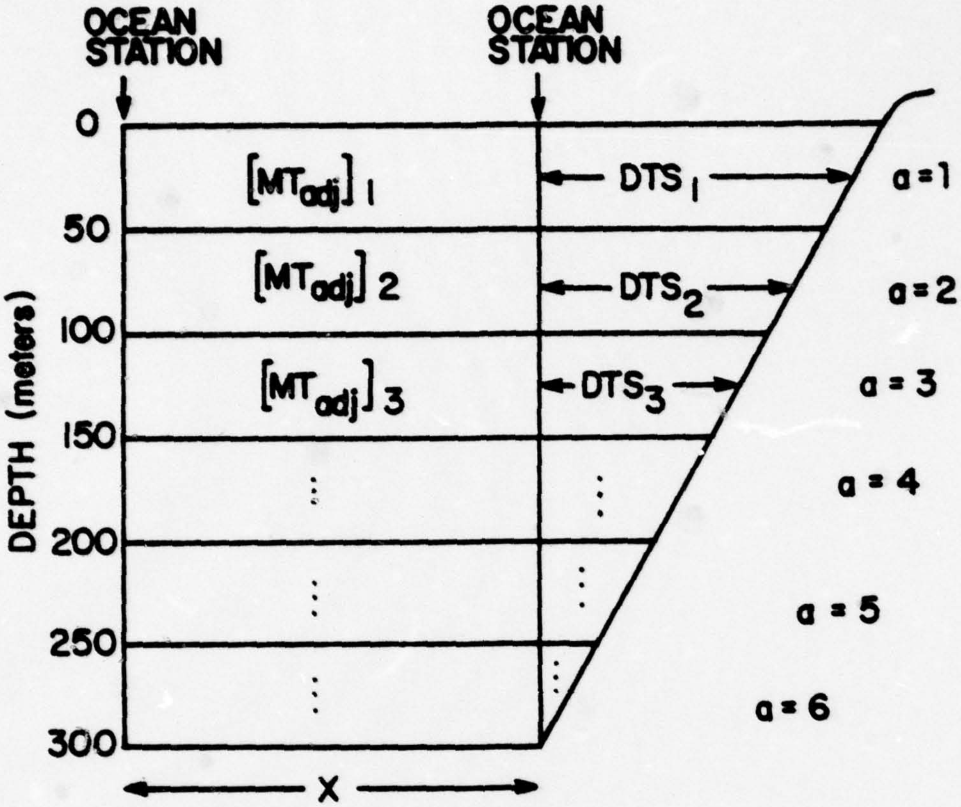
Peripheral area contributions are the mass, salt, and heat transport values obtained between the shorelines of bounding land masses and the most shoreward oceanographic station utilized for that particular latitude cross section.

Peripheral area contributions can be significant to the total net transports depending on their cross-sectional areas and inherent current velocities contained therein. One should be particularly aware of them in areas where a strong meridional current lies close to the end of an oceanic latitudinal cross section. Examples of this include the Gulf Stream and Kuroshio Current systems.

Figure 8 illustrates the procedure utilized to calculate the peripheral area contributions in this study. Mass transport is assumed to have a linear decrease from the most shoreward station mass transport value to zero mass transport at the shore. In addition, mass transport is calculated as a percentage of the mass transport previously calculated between the adjacent pair of stations. The percentage is the ratio of the distance between the shore and the closest oceanographic station to the distance over which the closest mass transport was calculated. Equation (6) illustrates the basic formula:

$$[MT_p]_a = 0.5[MT_{adj}]_a \frac{[DTS]_a}{x} , \qquad (6)$$

where a is the level where shore slope intersects most shoreward oceanographic station cast, $[MT_p]_a$ is the peripheral mass



$$[MT_p]_a = .5 \quad [MT_{adj}]_a \frac{[DTS]_a}{X}$$

Where a = 1 to level where shore slope intersects most shoreward oceanographic station cast.

PERIPHERAL AREA CONTRIBUTION EXAMPLE

Figure 8

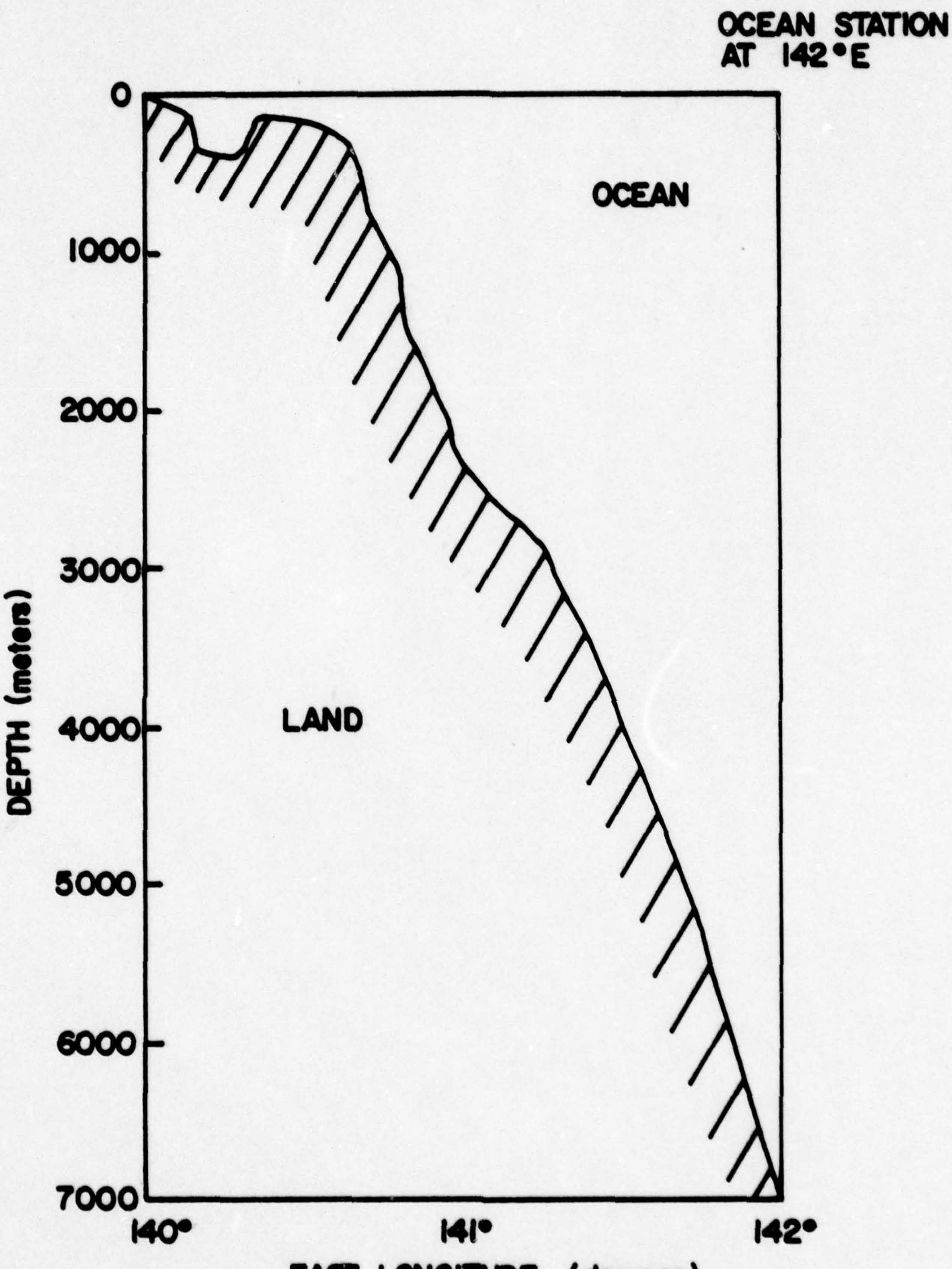
transport at level a; 0.5 is the factor to account for linear decrease of mass transport to shore, $[MT_{adj}]_a$ is the adjacent mass transport at level a, DTS is the distance from the closest oceanographic station to the shore, and x is the distance across which the adjacent mass transport was previously calculated.

The peripheral mass transports are then vertically summed and include a bottom area contribution under the peripheral area. Peripheral salt and heat transports are found by multiplying the peripheral mass transport by the salinity and temperature at the closest oceanographic station, averaged between standard depths.

The western end (Japan) of the 35°N latitude section produced a significant amount of transport contribution. This was due mainly to three reasons. First, the closest deep oceanographic station utilized was at 142°E longitude, which was about 180 kilometers from shore. This distance was much larger than the usual peripheral area distance to shore. Second, the bottom descended rapidly from the shores of Japan to 7000 meters within this 180 kilometer distance. Third, the strong Kuroshio Current was present in this area and produced a great deal of mass transport in this peripheral area.

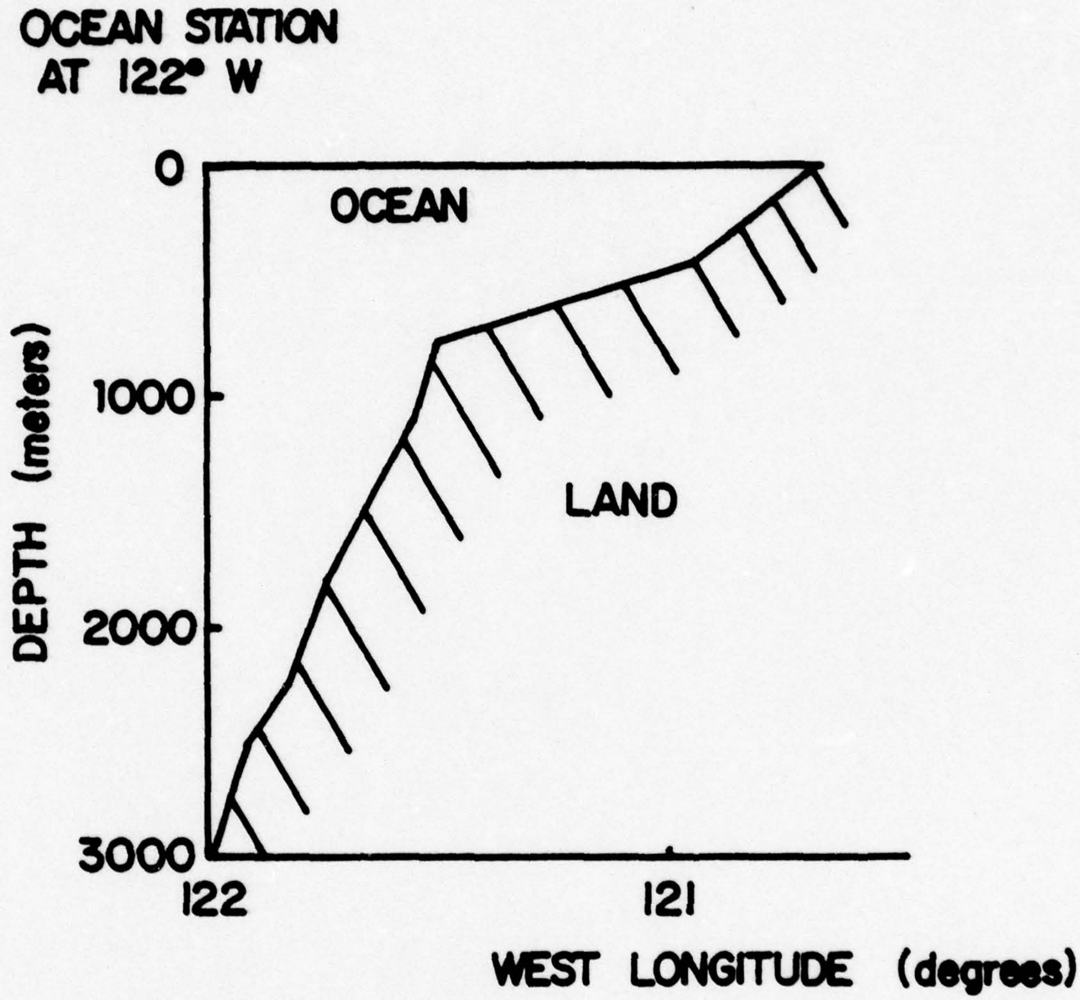
The peripheral area contribution for the eastern end (California) of the 35°N latitude cross section produced only a small transport contribution. This was in contrast to the western area since it encompassed only 108 kilometers, the bottom descended only to 2500 meters, and the ocean current system was not nearly as strong as the Kuroshio system.

Figures 9 and 10 illustrate the peripheral areas included in this study. The peripheral area between Japan and Korea (along 35°N) in the Korea and Tsushima Straits was neglected since its water circulation was not considered integral to the North Pacific circulation, and it is assumed to contribute a negligible amount of net transport across the latitude.



PERIPHERAL AREA CONTRIBUTION FROM JAPANESE COAST AT 35°N LATITUDE IN THE PACIFIC OCEAN

Figure 9



PERIPHERAL AREA CONTRIBUTION FROM CALIFORNIA COAST AT 35°N IN THE PACIFIC OCEAN

Figure 10

V. DISCUSSION OF RESULTS

A. THE LEVEL OF NO MOTION, MASS TRANSPORT, AND SALT TRANSPORT

One of the objectives of this study was to establish a constant LNM across the North Pacific Ocean along 35°N for which mass and salt transports were approximately zero. The LNM was determined with the primary requirement of a mass transport of zero. The LNM was determined to be 880 meters when considering the main data only. Hereafter, main data refers to all the cruise data (140°E to 122°W) plus bottom area contributions but not peripheral area contributions. Total data refers to the main data plus peripheral data.

Since the peripheral areas had a significant contribution to mass transport, the requirement for a LNM solution was for the mass transport to be near zero for the total data vice only the main data. As can be seen in Table II, the LNM was extremely sensitive to the small but significant peripheral area contributions. Thus, the final LNM for the total data was established at 851 meters. The graph in Figure 11 illustrates the sensitivity of mass transport for the three areas - main, Japanese peripheral area, and California peripheral area - as a function of slope. The steeper the slope, the less sensitive is the mass transport to depth changes. Note the extreme sensitivity of the

TABLE II

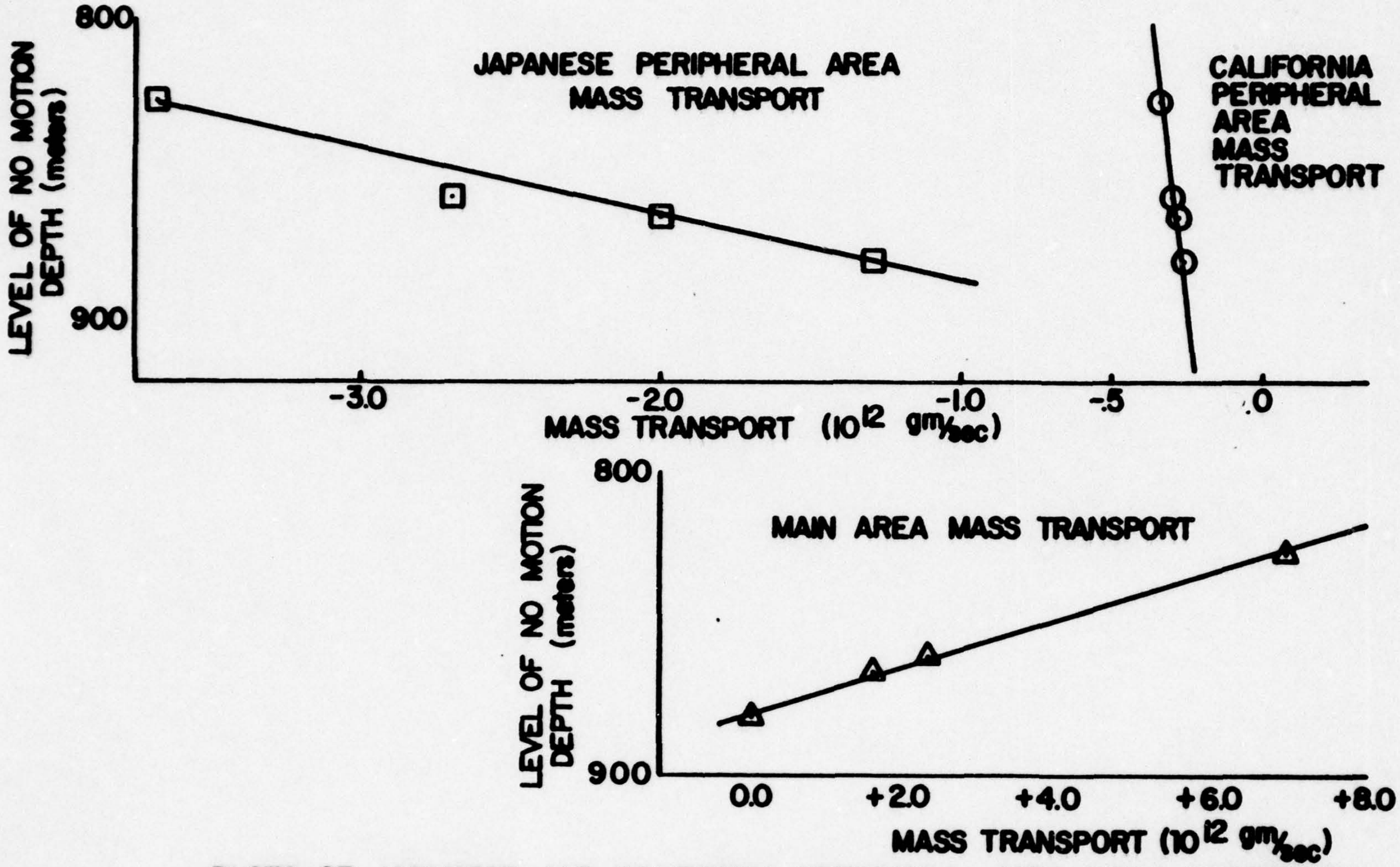
VARIATION OF TOTAL MASS TRANSPORT AND HEAT TRANSPORT WITH VARIOUS DEPTHS OF THE LEVEL OF NO MOTION

DEPTH OF THE LNM (METERS)	MAIN MT	MAIN HT	JAP MT	JAP HT	CAL MT	CAL HT	TOTAL MT	TOTAL HT
826	6.99	1590.	-3.68		-.35		2.96	
851	3.295	567.	-2.965	-767.5	-.315	-87.5	.015*	-288.
852	3.18	534.	-2.94	-760.	-.31	-87.	-.07	-313.
854	2.92	463.	-2.88	-743.	-.31	-86.	-.27	-366.
858	2.42	324.	-2.70	-713.	-.30	-84.	-.58	-473.
859	2.42	292.	-2.70	-705.	-.30	-84.	-.70	-497.
865	1.58	92.9	-2.5		-.29		-1.21	
880	-.05*	-362.	-1.3		-.27		-1.62	

*Minimum value of mass transport

NOTE:

1. Abbreviations used: mass transport (MT), heat transport (HT), Japanese peripheral area (JAP), California periperhal area (CAL).
2. Negative values indicate southward transport.
3. Total values equal main plus both peripheral areas.
4. Bottom area contributions are included.
5. MT has units of 10^{12} gm/sec and HT has units of 10^{12} cal/sec.
6. The LNM without peripheral areas was determined to be 880 meters whereas the final LNM, which includes peripheral areas, was determined to be 851 meters.



PLOTS OF JAPANESE AND CALIFORNIA PERIPHERAL AREA MASS TRANSPORT AND MAIN AREA MASS TRANSPORT VERSUS DEPTH OF THE LEVEL OF NO MOTION

Figure 11

Japanese peripheral area mass transport to depth due to the large horizontal area involved and the strength of the Kuroshio Current.

The corresponding total salt transport for the LNM set at 851 meters was 16.27 x 10^{12} ^{o}/oo/sec toward the polar region.

B. HEAT TRANSPORT

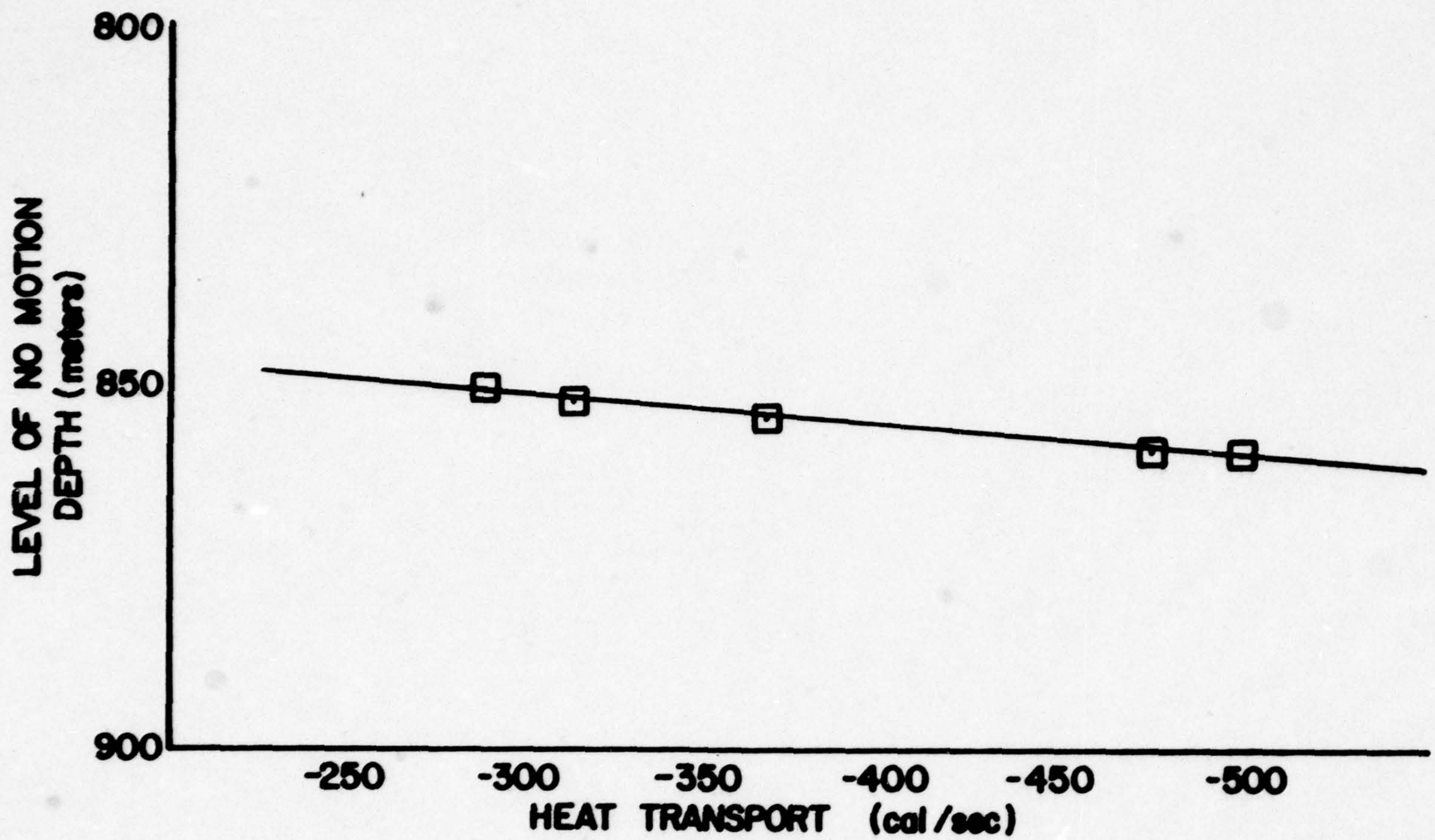
Measurement of the heat transport across the 35°N latitudinal section was a prime objective of this study. The expression, $C_{ps}(T_n-T_s)\rho_s V_{ns}$, represents the net meridional transport of heat across a latitude section of the ocean, where ρ_s V_{ns} is the meridional mass transport, T_n is the northward moving water temperature, and T_s is the southward moving water temperature (Baker, 1978). C_{ps} is the specific heat at constant pressure of seawater which we may assume to be unity (Sverdrup *et al.*, 1942).

Mass continuity requires that for a mass balance to exist across a latitude section, the northward mass transport must cancel the southward mass transport. However since the temperatures of the waters transported in opposing directions may differ, a net meridional flux of heat may be established. Sverdrup (1955) and Vonder Haar and Oort (1973) have proposed other methods of measuring meridional heat transport, but only this method utilizes direct measurements of temperature and salinity.

Table II contains the net meridional heat transports for the main data, Japan peripheral area, California peripheral

area, and the total data for various levels. Utilizing the established LNM of 851 meters yielded a southward heat transport of 288 x 10^{12} cal/sec. Figure 12 is a graph of the total meridional heat transports versus changes in the depth of the LNM. Note the extreme sensitivity of heat transport values to small changes in the depth of the LNM.

Table III compares results of other studies on heat transport in the North Pacific Ocean with the value calculated here. If one is to maintain continuity and thermal equilibrium of the ocean, then a heat gain in the North Pacific indicates a southward heat flux. Otherwise the North Pacific would continue to get warmer with each year. Patullo (1957) used radiation values by Black (1956) and calculated a heat gain of 120 x 10^{12} cal/sec for the North Pacific Ocean. Albrecht (1960) used $\Sigma Q = 0$ for all oceans as a basic criterion and calculated a heat gain for the North Pacific at a rate of 157 x 10^{12} cal/sec. Bryan (1962) used heat balance maps of the oceans compiled by Budyko (1956) and Albrecht (1960) and data from the NORPAC Pacific section made in August 1955 at 35°N to arrive at 224 x 10^{12} cal/sec southward heat transport. Wyrtki (1965) calculated the heat exchange for the Pacific Ocean north of 20°S using climatic data for the period 1947-1960, averaged over 2° squares and months. He concluded there is a heat gain at the average rate of 300 x 10^{12} cal/sec. Emig (1967) found a northward heat flux for the entire North Pacific Ocean although there was a southward heat flux across the equatorial Pacific.



PLOT OF TOTAL HEAT TRANSPORT VS. DEPTH OF THE LEVEL OF NO MOTION
(NEGATIVE TRANSPORT INDICATES SOUTHWARD TRANSPORT)

Figure 12

TABLE III

COMPARISON OF HEAT TRANSPORT IN THE NORTH PACIFIC OCEAN WITH ESTIMATES BY OTHER AUTHORS
(negative values indicate southward transport)

AUTHOR (date of publication)		HEAT TRANSPORT ($\times 10^{12}$ cal/sec)
Sverdrup	(1957)	northward heat transport
Patullo	(1957)	-120
Albrecht	(1960)	-157
Bryan	(1962)	-224
Wyrtki	(1965)	-300*
Emig	(1967)	northward heat transport
Tabata	(1975)	southward heat transport
Whitford	(1979)	-288

*includes all of Pacific Ocean north of 20°S

The heat budget method was used to compute heat flux divergence and the meridional heat transport was calculated by integrating the heat flux divergence according to Green's theorem. Tabata (1975) concluded that "the overall heat transport in the North Pacific must be equatorward and it is difficult to imagine it otherwise."

However, earlier estimates by Sverdrup (1957) and numerical models of the ocean-atmosphere climatic models (Bryan, 1969; Manabe, 1969; Bryan et al., 1975; Manabe et al., 1975) indicate a net poleward transport of heat (Tabata, 1975). Vonder Haar and Oort (1973) also concluded there is a net poleward heat transport in the North Pacific using improved estimates of radiative flux values from satellite observations.

VI. CONCLUSIONS

This work represents a synoptic study conducted in the North Pacific Ocean to determine total mass, salt, and heat transports from a calculation of geostrophic currents where determination of a LNM was required. Its data base covered a complete cross-sectional area from the shoreline of Japan to the shoreline of California and from the ocean surface to the ocean floor itself.

Magnetic tape data handling procedures were streamlined, a subroutine to enable the computer to automatically determine the LNM was developed, and extensive documentation was added to a Department of Oceanography, Naval Postgraduate School computer program to save future research time in utilizing the program.

A LNM was determined at a depth of 851 meters for 35° North latitude in the North Pacific Ocean. This level was determined by including peripheral and bottom area contributions. The inclusion of these areas had a significant effect on the determination of the LNM. Figure 11 and Table II show the sensitivity inherent in this area.

A northward salt transport of 16.27×10^{12} $^{o}/oo$/sec was determined. This value was not as close to zero as desired but still remained within the order of magnitude of previous studies that used this method in other oceans.

An equatorward heat transport of 288 x 10^{12} cal/sec was determined for this cross section. Figure 12 and Table II show the extreme sensitivity of heat transport values to variations in the depth of the LNM.

The upper water masses had southward transport values approximately equal to the combined northward transport values of the middle, deep, and bottom water masses (Table IV). This implies a shallow but strong southward transport in the upper 300 to 400 meters balanced by a very thick but weak northward transport at depths from 400 meters to the ocean floor, nearly 5000 meters deeper. It would have been expected that most of the heat transport would take place in the upper waters where the temperatures and currents are much higher and stronger. However this study showed that the lower temperatures found at depth, transported at slower velocities, can balance the upper waters' heat transport, due to the tremendous volume of middle, deep, and bottom water. Therefore oceanic heat transport must take into account transport at <u>all</u> depths and not just consider the surface layers.

The heat transport value determined for this study was consistent with several previous determinations using different models (Table III). Deviations between different authors' results may be due to seasonal effects and synopticity (or lack of it) in the data utilized. The extreme sensitivity of heat transport values versus depth of the LNM (Figure 12) must be considered when reviewing a study's results.

TABLE IV

MAIN TRANSPORTS ACROSS 35°N LATITUDE
IN THE PACIFIC OCEAN

BY WATER MASS TYPE:

WATER MASS	MASS	SALT	HEAT
Surface	-11.79991	-406.27979	-3418.89063
California	-6.28005	-210.78185	-1792.93896
North Pacific Central	-15.14672	-520.27710	-4298.21875
Intermediate	0.17608	10.20034	75.96964
Pacific Sub-arctic	18.24092	629.33716	5025.82031
Deep	18.10057	627.32690	4974.23828

BY EACH OF THREE LAYERS:

WATER MASS	MASS	SALT	HEAT
Upper	-33.22667	-1137.33862	-9510.04688
Middle	18.41699	639.53735	5101.78906
Deep and Bottom	18.10057	627.32690	4974.23828
MAIN TOTAL	3.29089	129.52563	565.98046

NOTE:

1. Negative values indicate southward transports. Data is for a LNM of 851 meters.
2. Mass, salt, and heat transports have units of 10^{12} gm/sec, 10^{12} ‰/sec, and 10^{12} cal/sec, respectively.
3. The total for mass transport does not approach zero since peripheral areas are not included in this table. Small differences in the grand total from Table II are due to truncation error.
4. Upper water mass includes Surface, Central, and California water masses, and middle water mass includes Intermediate and Pacific Subarctic water masses.

If there is a southward transport of heat by the North Pacific Ocean as indicated by this and other studies, then this may be associated with high atmospheric heat transport to the poles, more than required for planetary radiation balance. The ocean would then act to compensate this excess activity by the atmosphere. Further work in this area is desirable to substantiate this idea.

APPENDIX A

MAGNETIC COMPUTER TAPE PROCEDURES

Cruise data from Scripps Institution of Oceanography, La Jolla, California, were made available to the Naval Postgraduate School in card image format (Appendix D) on a magnetic computer tape. They were recorded at 1600 BPI on a non-labeled nine track tape. This appendix will describe the procedures utilized to manipulate that data to a form economical and compatible with the IBM 360/67 computer and this study's computer program and to provide a backup data medium in case of data erasure on the primary data medium. Utilization of these procedures should save considerable time for future work in this area.

The primary data medium was chosen as computer cards with a backup medium as a magnetic computer tape. These selections were made for several reasons. Magnetic tape usage slows down each computer program turnaround since the computer operator must manually load the tape each time the program is run. In addition, this manual loading precludes running programs whenever the computer center is on automatic (non-operator) handling such as during portions of the weekend. Computer cards offer ease in editing without using the computer. Once the cards are in the form desired, they are loaded as a user library on a direct access device, i.e., a 3330 disk. This keeps the data stored permanently at the Computer Center and is accessed with a small JCL modification

in the program. The required steps to accomplish these procedures are described next.

Upon receipt of the Scripps Institution tape data, it is given to the Computer Center and assigned a name by the user. For this example, NPAC was the name assigned.

The next step in handling the Scripps Institution data is to determine the contents of the tape and to confirm that it follows the card image format specified in Appendix D. This is accomplished by using a general purpose tape dump program entitled TAPEOUT using the following card format:

```
// (STANDARD JOB CARD)
// EXEC TAPEOUT,PARM='1,0,0,2,0',VOL=NPAC,UNIT=254
/* (ORANGE)
```

After confirming that the information is in the proper format, the non-labeled Scripps tape must be copied onto another magnetic tape as a standard labeled tape for ease in handling. The Computer Center assigns an NPS number to the tape (NPS278 for example) and the step is accomplished with the following job control language:

```
// (STANDARD JOB CARD)
//ONE  EXEC  PGM=IEBGENER
//SYSPRINT  DD  SYSOUT=A
//SYSIN  DD  DUMMY
//SYSUT1  DD  UNIT=3400-4,VOL=SER=NPAC,
//  DISP=(OLD,PASS),LABEL=(,NL),DCB=(RECFM=B,BLKSIZE=80)
//SYSUT2  DD  UNIT=3400-3,VOL=SER=NPS278,
//  DISP=(,PASS),DCB=(RECFM=FB,LRECL=80,BLKSIZE=3200,DEN=3),
//  LABEL=(,SL),DSN=FILE1
/* (ORANGE)
```

This new standard labeled nine-track tape named NPS278 is now punched out on the primary medium of computer cards as follows:

```
// (STANDARD JOB CARD)
//  EXEC  PGM=IEBPTPCH
//SYSPRINT  DD  SYSOUT=A
//SYSUT1   DD   UNIT=3400-4,VOL=SER=NPS278,DISP=(OLD,KEEP),
//    LABEL=(,SL),DSN=CARDS
//SYSUT2   DD   SYSOUT=B
//SYSIN   DD   *
   PUNCH
/* (ORANGE)
```

The computer card data may be edited to match the program data input format for uniformity with previous studies and for ease in reading the computer cards or the program's input format statement may be changed to match the cards.

When the data cards are in their final form they are placed on a permanent disk with the following job control language:

```
// (STANDARD JOB CARD)
// EXEC PGM=IEBGENER
//SYSPRINT DD SYSOUT=A
//SYSIN DD DUMMY
//SYSUT2 DD UNIT=3330,VOL=SER=DISK01,SPACE=(TRK,(20,1),
    RLSE),
// DISP=(NEW,KEEP),DSN=S2557.COMBINED.MINUS.JAPAN,
    LABEL=EXPDT=79176,
// DCB=(RECFM=FB,LRECL=80,BLKSIZE=6400)
//SYSUT1 DD *
    -data cards-
/* (ORANGE)
```

where DISK01 is one of the four disks available for storage, and S2557.MINUS.JAPAN is the name assigned by the user to this data set on the disk, S indicates student and 2557 is the user's number. In this example, the data set consisted of 3000 cards. Since one track, blocked at 6400, will hold 160 card images, therefore 20 tracks will be required for storage.

Now that the data are stored on DISK01, the data may be accessed for the program with the following job control

language:

```
// (STANDARD JOB CARD)
// EXEC FORTCLG,REGION.GO=200K
//FORT.SYSIN DD *
    (program deck)
//GO.FT08F001  DD DUMMY
//GO.FT01F001  DD UNIT=3330,VOL=SER=DISK01,DISP=SHR,
// DSNAME=S2557.COMBINED.MINUS.JAPAN,
// DCB=(RECFM=FB,LRECL=80,BLKSIZE=6400),
// LABEL(,,,IN)
//GO.SYSIN DD *
    (data cards, if any)
/*
```

The dummy 8 JCL card is useful when no printout is desired on some statements (WRITE(8,....)) but desired on others (WRITE(6,...)). The LABEL (,,,IN) insures access to the stored data on DISK01 without computer operator assistance. This allows the program to be run during automated (non-operator) computer hours.

Detailed explanations of these procedures can be found in the W. R. Church Computer Center User's Manual, Naval Postgraduate School, Monterey, California.

APPENDIX B

STATION PAIRS

The first section of this appendix lists the station pairs utilized in calculating geostrophic currents for this study. The station pair numbers are useful in interpreting Appendix C and are utilized in this study only. The cruise station indicates the cruise name and cruise assigned oceanographic station numbers. Where data had to be combined from two cruises, the location and date are that of the INDOPAC XVI cruise.

The second section of this appendix is a list of INDOPAC I oceanographic stations not utilized in this study due to shallowness of cast.

SECTION I - STATION PAIRS UTILIZED

STATION PAIR	CRUISE STATION	LATITUDE/LONGITUDE	DATE
	INDOPAC I-1	35-03.5N/121-56.2W	25 Mar 76
1.			
	INDOPAC I-3	35-00.0N/124-00.0W	26 Mar 76
2.			
	INDOPAC I-7	34-59.0N/128-03.2W	28 Mar 76
3.			
	INDOPAC I-9	35-00.0N/130-01.4W	29 Mar 76
4.			
	INDOPAC I-11	35-01.2N/132-03.5W	29 Mar 76
5.			
	INDOPAC I-13	34-59.2N/134-02.0W	30 Mar 76
6.			
	INDOPAC I-17	35-00.3N/137-59.0W	31 Mar 76
7.			
	INDOPAC XVI-26/ INDOPAC I-19	35-10.6N/139-58.0W	24 Jul 77
8.			
	INDOPAC XVI-24/ INDOPAC I-21	35-09.3N/142-00.3W	23 Jul 77
9.			
	INDOPAC XVI-22/ INDOPAC I-23	35-10.3N/143-59.8W	22 Jul 77
10.			
	INDOPAC XVI-20/ INDOPAC I-25	35-10.4N/145-59.1W	22 Jul 77
11.			
	INDOPAC XVI-18/ INDOPAC I-27	35-10.4N/147-58.3W	20 Jul 77
12.			
	INDOPAC XVI-16/ INDOPAC I-29	35-10.4N/149-59.5W	18 Jul 77
13.			
	INDOPAC XVI-14/ INDOPAC I-31	35-10.1N/151-57.0W	17 Jul 77
14.			
	INDOPAC XVI-12/ INDOPAC I-33	35-09.9N/153-58.0W	17 Jul 77
15.			
	INDOPAC XVI-10/ INDOPAC I-35	35-09.9N/156-02.4W	15 Jul 77
16.			
	INDOPAC XVI-8/ INDOPAC I-37	35-09.2N/158-00.0W	14 Jul 77
17.			
	INDOPAC XVI-6/ INDOPAC I-39	35-10.8N/159-59.2W	13 Jul 77

18.	INDOPAC XVI-4/ INDOPAC I-41	35-09.2N/162-01.2W	7 Jul 77
19.	INDOPAC I-43	35-00.0N/163-59.3W	8 Apr 76
20.	INDOPAC I-45	34-57.0N/166-00.0W	9 Apr 76
21.	INDOPAC I-47	35-02.2N/168-00.5W	9 Apr 76
22.	INDOPAC I-49	35-00.8N/170-00.0W	10 Apr 76
23.	INDOPAC I-51	34-56.6N/172-02.0W	11 Apr 76
24.	INDOPAC I-53	35-00.6N/174-02.0W	11 Apr 76
25.	INDOPAC I-55	34-58.4N/175-59.8W	12 Apr 76
26.	INDOPAC I-57	35-01.0N/178-01.2W	13 Apr 76
27.	INDOPAC I-59	34-59.3N/179-59.6E	13 Apr 76
28.	INDOPAC I-61	34-59.0N/177-58.4E	14 Apr 76
29.	INDOPAC I-63	34-58.5N/175-57.8E	15 Apr 76
30.	INDOPAC I-65	35-00.0N/174-00.3E	16 Apr 76
31.	INDOPAC I-66	35-01.0N/173-02.5E	16 Apr 76
32.	INDOPAC I-67	34-59.7N/172-01.3E	17 Apr 76
33.	INDOPAC I-68	35-00.0N/171-00.7E	17 Apr 76
34.	INDOPAC I-69	34-58.6N/170-03.5E	17 Apr 76
35.	INDOPAC I-71	34-59.4N/168-00.0E	18 Apr 76
36.	INDOPAC I-73	35-01.8N/166-01.0E	19 Apr 76
37.	INDOPAC I-75	35-04.0N/164-08.0E	20 Apr 76
38.	INDOPAC I-77	34-59.0N/162-04.5E	20 Apr 76
39.	INDOPAC I-79	35-02.0N/160-06.0E	21 Apr 76
40.	INDOPAC I-81	34-59.2N/157-56.0E	22 Apr 76
41.	INDOPAC I-83	35-03.3N/155-55.5E	23 Apr 76
42.	INDOPAC I-85	34-58.5N/153-57.8E	23 Apr 76

43.	INDOPAC I-87	35-02.0N/151-54.5E	24 Apr 76
44.	INDOPAC I-89	35-00.0N/149-52.0E	25 Apr 76
45.	INDOPAC I-91	34-56.5N/147-59.4E	25 Apr 76
46.	INDOPAC I-92	35-12.2N/147-00.3E	26 Apr 76
47.	INDOPAC I-93	34-58.2N/146-01.0E	26 Apr 76
48.	INDOPAC I-95	34-58.5N/144-00.5E	27 Apr 76
49.	INDOPAC I-97	35-03.0N/142-01.4E	28 Apr 76

SECTION II

LIST OF INDOPAC I OCEANOGRAPHIC STATIONS NOT UTILIZED IN THIS STUDY DUE TO SHALLOWNESS OF CAST

CRUISE STATION NUMBER	LATITUDE/LONGITUDE	DATE	DEEPEST CAST (METERS)
2	34-58.0N/123-05.1W	26 Mar 76	1200
4	34-59.3N/124-59.8W	27 Mar 76	1000
5	35-00.7N/126-01.0W	27 Mar 76	1646
6	35-01.0N/126-59.1W	28 Mar 76	1200
8	34-58.8N/129-02.2W	28 Mar 76	1200
10	35-01.6N/131-00.6W	29 Mar 76	1200
12	34-59.3N/133-00.3W	30 Mar 76	1200
14	34-58.7N/134-59.0W	30 Mar 76	1200
15	35-00.4N/136-02.8W	31 Mar 76	1000
16	34-59.1N/137-00.7W	31 Mar 76	1205
18	35-01.2N/139-00.0W	1 Apr 76	1200
20	35-00.5N/141-00.1W	2 Apr 76	1200
22	34-59.4N/143-00.8W	2 Apr 76	1200
24	34-59.2N/144-59.9W	3 Apr 76	1200
26	34-58.8N/147-00.7W	3 Apr 76	1200
28	35-00.1N/148-59.9W	4 Apr 76	1200
30	34-59.8N/151-00.4W	4 Apr 76	1200
32	34-59.5N/153-02.1W	5 Apr 76	1200
34	34-59.9N/155-02.2W	5 Apr 76	1200
36	34-58.6N/157-00.2W	6 Apr 76	1200
38	35-00.0N/159-00.4W	6 Apr 76	1200
40	35-00.2N/161-02.3W	7 Apr 76	1200
42	34-58.8N/162-59.8W	7 Apr 76	1160
44	34-59.6N/165-00.3W	8 Apr 76	1200
46	35-01.6N/166-58.0W	9 Apr 76	1200
48	34-59.7N/168-59.6W	10 Apr 76	1200
50	34-59.4N/171-00.9W	10 Apr 76	1156
52	35-01.6N/172-59.9W	11 Apr 76	1200
54	34-59.3N/175-00.8W	12 Apr 76	1200
56	35-00.4N/176-58.1W	12 Apr 76	1139
58	34-59.6N/179-00.6W	13 Apr 76	1200
60	34-59.8N/179-00.5E	14 Apr 76	1200
62	34-59.1N/176-58.3E	15 Apr 76	1200
64	35-01.1N/175-01.2E	15 Apr 76	1200
70	34-59.5N/168-56.9E	18 Apr 76	1200
72	35-00.5N/167-00.9E	18 Apr 76	1200
74	35-00.1N/165-00.4E	19 Apr 76	1008
76	34-57.9N/162-58.4E	20 Apr 76	1200
78	35-00.5N/161-00.1E	21 Apr 76	1128
80	34-57.6N/158-57.7E	22 Apr 76	1200

82	35-02.1N/156-57.3E	22 Apr 76	1137
84	34-59.2N/155-00.6E	23 Apr 76	1139
86	34-57.9N/152-54.6E	24 Apr 76	1116
88	35-00.1N/150-58.5E	24 Apr 76	1163
90	34-58.4N/148-59.0E	25 Apr 76	1200
94	34-53.6N/144-58.1E	27 Apr 76	800
96	35-01.8N/142-57.3E	28 Apr 76	1200
98	35-02.4N/140-59.4E	29 Apr 76	717

APPENDIX C

MASS, SALT, AND HEAT TRANSPORTS BY LOCATION AND WATERMASS

The following pages contain the net mass, salt, and heat transports for each water mass of each station pair. The location of indicated station pair is obtained from Appendix C. Mass, salt, and heat transport values are in units of 10^{12} gm/sec, 10^{12} ^{o}/oo/sec, and 10^{12} cal/sec, respectively. Negative values indicate equatorward transports.

WATER MASS	MASS	SALT	HEAT
Station Pair 1: INDOPAC I-1 to INDOPAC I-3			
Surface	0.0	0.0	0.0
California	-0.34410	-11.52099	-97.74341
N. Pac. Central	0.0	0.0	0.0
Intermediate	0.37084	12.66023	103.64563
Subarctic	-5.63105	-194.77899	-1551.80078
Deep	0.0	0.0	0.0
Subtotal	-5.60431	-193.63974	-1545.89844
Station Pair 2: INDOPAC I-3 to INDOPAC I-7			
Surface	0.0	0.0	0.0
California	0.27527	9.20514	78.04015
N. Pac. Central	0.0	0.0	0.0
Intermediate	0.61529	20.98962	171.76651
Subarctic	0.27827	9.61501	76.79755
Deep	0.44796	15.52911	123.08189
Subtotal	1.61679	55.33887	449.68579
Station Pair 3: INDOPAC I-7 to INDOPAC I-9			
Surface	0.0	0.0	0.0
California	-4.10131	-136.99156	-1167.87720
N. Pac. Central	0.0	0.0	0.0
Intermediate	-2.91873	-99.37216	-816.09326
Subarctic	5.43740	187.97072	1497.94897
Deep	12.81396	444.25488	3520.31567
Subtotal	11.23132	395.86182	3034.29419
Station Pair 4: INDOPAC I-9 to INDOPAC I-11			
Surface	0.0	0.0	0.0
California	0.88616	29.67451	253.34891
N. Pac. Central	0.0	0.0	0.0
Intermediate	0.34405	11.72090	96.07492
Subarctic	-4.41877	-152.79330	-1216.86426
Deep	-15.19988	-527.01074	-4175.45313
Subtotal	-18.38843	-638.40845	-5042.89063

WATER MASS	MASS	SALT	HEAT
Station Pair 5: INDOPAC I-11 to INDOPAC I-13			
Surface	0.0	0.0	0.0
California	-1.84389	-62.03488	-528.31152
N. Pac. Central	0.0	0.0	0.0
Intermediate	-0.45856	-15.60684	-128.28625
Subarctic	1.83607	63.51488	505.69043
Deep	8.53072	295.80396	2343.43359
Subtotal	8.06434	281.67700	2192.52612
Station Pair 6: INDOPAC I-13 to INDOPAC I-17			
Surface	0.0	0.0	0.0
California	0.01177	0.40524	3.65422
N. Pac. Central	0.0	0.0	0.0
Intermediate	-0.86966	-29.56479	-244.23706
Subarctic	0.37648	12.98822	104.00803
Deep	-0.20602	-7.14607	-56.58417
Subtotal	-0.68742	-23.31738	-193.15898
Station Pair 7: INDOPAC I-17 to INDOPAC XVI-26/I-19			
Surface	0.0	0.0	0.0
California	-0.25076	-8.51281	-72.29599
N. Pac. Central	0.0	0.0	0.0
Intermediate	0.00163	0.05310	0.60259
Subarctic	-0.38189	-13.21926	-105.05971
Deep	-2.92392	-101.38283	-803.17651
Subtotal	-3.55495	-123.06178	-979.92944
Station Pair 8: INDOPAC XVI-26/I-19 to INDOPAC XVI-24/I-21			
Surface	0.0	0.0	0.0
California	-0.67032	-22.73459	-192.23236
N. Pac. Central	0.0	0.0	0.0
Intermediate	-0.77323	-26.31097	-216.78447
Subarctic	1.40092	48.44319	385.73755
Deep	7.75134	268.75513	2129.20654
Subtotal	7.70871	268.15259	2105.92725

WATER MASS	MASS	SALT	HEAT
Station Pair 9:	INDOPAC XVI-24/I-21 to INDOPAC XVI-22/I-23		
Surface	0.0	0.0	0.0
California	0.14009	4.75861	40.34361
N. Pac. Central	0.06472	2.20394	18.72963
Intermediate	-0.16206	-5.51509	-45.28922
Subarctic	-0.15259	-5.30570	-41.80907
Deep	-3.12593	-108.38799	-858.62622
Subtotal	-3.23577	-112.24622	-886.65112
Station Pair 10:	INDOPAC XVI-22/I-23 to INDOPAC XVI-20/I-25		
Surface	-0.19286	-6.59413	-55.91312
California	-0.23427	-7.96909	-67.12183
N. Pac. Central	-0.09939	-3.39154	-28.21126
Intermediate	-0.50310	-17.12782	-141.05803
Subarctic	1.15238	39.81818	317.52393
Deep	3.00631	104.23486	825.79907
Subtotal	3.12908	108.97046	851.01855
Station Pair 11:	INDOPAC XVI-20/I-25 to INDOPAC XVI-18/I-27		
Surface	-0.54651	-18.67084	-157.45361
California	0.0	0.0	0.0
N. Pac. Central	-0.31730	-10.84622	-90.09114
Intermediate	-0.65235	-22.21384	-182.97899
Subarctic	0.38166	13.18303	105.17566
Deep	2.88119	99.89867	791.41943
Subtotal	1.74669	61.35081	466.07153
Station Pair 12:	INDOPAC XVI-18/I-27 - INDOPAC XVI-16/I-29		
Surface	-0.38788	-13.24891	-111.82310
California	-0.14872	-5.06161	-42.74556
N. Pac. Central	-0.20832	-7.12382	-59.20682
Intermediate	-0.57257	-19.50002	-160.58276
Subarctic	1.66544	57.54994	458.81104
Deep	4.96733	172.21225	1364.54297
Subtotal	5.31527	184.82785	1448.99561

WATER MASS	MASS	SALT	HEAT
Station Pair 13:	INDOPAC XVI-16/I-29 to INDOPAC XVI-14/I-31		
Surface	0.78088	26.74231	226.41249
California	0.0	0.0	0.0
N. Pac. Central	1.61227	54.97591	459.87744
Intermediate	1.78792	60.88583	501.13086
Subarctic	-3.87340	-133.81140	-1067.35962
Deep	-11.13172	-385.91162	-3057.64551
Subtotal	-10.82405	-377.11890	-2937.58447
Station Pair 14:	INDOPAC XVI-14/I-31 to INDOPAC XVI-12/I-33		
Surface	-0.28040	-9.56191	-80.05515
California	0.0	0.0	0.0
N. Pac. Central	-0.40749	-13.91642	-115.52618
Intermediate	-0.87127	-29.67528	-244.27370
Subarctic	1.69664	58.62651	467.40771
Deep	5.46245	189.37157	1500.40381
Subtotal	5.59993	194.84448	1527.95630
Station Pair 15:	INDOPAC XVI-12/I-33 to INDOPAC XVI-10/I-35		
Surface	0.82654	28.19444	237.31958
California	0.0	0.0	0.0
N. Pac. Central	0.29439	10.06885	83.49960
Intermediate	0.55431	18.88911	155.55942
Subarctic	-0.83490	-28.84314	-229.99123
Deep	-8.43979	-292.67847	-2318.19800
Subtotal	-7.59945	-264.36914	-2071.81055
Station Pair 16:	INDOPAC XVI-10/I-35 to INDOPAC XVI-8/I-37		
Surface	-1.18198	-40.38577	-339.25928
California	0.0	0.0	0.0
N. Pac. Central	-0.45812	-15.68106	-130.06287
Intermediate	-0.79329	-27.04507	-222.69713
Subarctic	2.30197	79.49214	634.26563
Deep	10.39701	360.55981	2855.87720
Subtotal	10.26558	356.93994	2798.12354

WATER MASS	MASS	SALT	HEAT
Station Pair 17:	INDOPAC XVI-8/I-37 to INDOPAC XVI-6/I-39		
Surface	0.02242	0.76722	6.62209
California	0.0	0.0	0.0
N. Pac. Central	-0.18901	-6.47177	-53.66077
Intermediate	-0.42116	-14.34603	-117.94626
Subarctic	-0.12354	-4.27237	-34.02327
Deep	1.17090	40.61169	321.63330
Subtotal	0.45961	16.28876	122.62511
Station Pair 18:	INDOPAC XVI-6/I-39 to INDOPAC XVI-4/I-41		
Surface	0.88051	30.15190	252.51637
California	0.0	0.0	0.0
N. Pac. Central	0.30463	10.42982	86.50900
Intermediate	0.75854	25.85313	212.76993
Subarctic	-1.68111	-58.07181	-463.06519
Deep	-7.67737	-266.20776	-2108.83472
Subtotal	-7.41479	-257.84473	-2020.10474
Station Pair 19:	INDOPAC XVI-4/I-41 to INDOPAC I-43		
Surface	-0.74362	-25.46718	-212.91193
California	0.0	0.0	0.0
N. Pac. Central	-0.32069	-10.97776	-91.05777
Intermediate	-0.78714	-26.83102	-220.81099
Subarctic	1.38000	47.65797	380.21387
Deep	4.70013	162.97961	1291.07642
Subtotal	4.22868	147.36163	1146.50977
Station Pair 20:	INDOPAC I-43 to INDOPAC I-45		
Surface	-0.44325	-15.20156	-127.09561
California	0.0	0.0	0.0
N. Pac. Central	-0.16323	-5.59268	-46.38217
Intermediate	-0.14943	-5.09439	-41.92204
Subarctic	0.91408	31.56805	251.83015
Deep	3.74671	129.92007	1029.19360
Subtotal	3.90487	135.59950	1065.62378

WATER MASS	MASS	SALT	HEAT
Station Pair 21:	INDOPAC I-45 to	INDOPAC I-47	
Surface	0.12034	4.13117	34.53850
California	0.0	0.0	0.0
N. Pac. Central	-0.02530	-0.86673	-7.18025
Intermediate	-0.06985	-2.38071	-19.70047
Subarctic	-1.17426	-40.57924	-323.38037
Deep	-5.17527	-179.46333	-1421.61304
Subtotal	-6.32435	-219.15883	-1737.33545
Station Pair 22:	INDOPAC I-47 to	INDOPAC I-49	
Surface	-0.19584	-6.73650	-56.23064
California	0.0	0.0	0.0
N. Pac. Central	-0.06179	-2.12041	-17.58345
Intermediate	-0.02443	-0.83227	-6.87055
Subarctic	-0.10402	-3.56950	-28.76265
Deep	2.88897	100.19978	793.53906
Subtotal	2.50289	86.94110	684.09155
Station Pair 23:	INDOPAC I-49 to	INDOPAC I-51	
Surface	-0.81059	-27.88806	-232.41499
California	0.0	0.0	0.0
N. Pac. Central	-0.75578	-25.92561	-214.95976
Intermediate	-0.57077	-19.45016	-160.00627
Subarctic	1.85098	63.94165	509.78687
Deep	5.43051	188.30228	1491.80713
Subtotal	5.14435	178.98009	1394.21289
Station Pair 24:	INDOPAC I-51 to	INDOPAC I-53	
Surface	0.91111	31.34311	261.09204
California	0.0	0.0	0.0
N. Pac. Central	0.62588	21.47806	178.06178
Intermediate	0.37658	12.83750	105.72375
Subarctic	-1.07073	-37.00085	-294.79590
Deep	-2.30496	-79.92809	-633.16870
Subtotal	-1.46212	-51.27026	-383.08691

WATER MASS	MASS	SALT	HEAT
Station Pair 25:	INDOPAC I-53 to INDOPAC I-55		
Surface	0.00052	0.01576	0.07195
California	0.0	0.0	0.0
N. Pac. Central	0.15641	5.36456	44.43938
Intermediate	0.23339	7.95134	65.29933
Subarctic	2.03157	70.32469	558.71191
Deep	0.0	0.0	0.0
Subtotal	2.42188	83.65634	668.52246
Station Pair 26:	INDOPAC I-55 to INDOPAC I-57		
Surface	-0.40339	-13.91084	-116.00259
California	0.0	0.0	0.0
N. Pac. Central	-0.12690	-4.35765	-36.11740
Intermediate	-0.24878	-8.48083	-69.91991
Subarctic	-0.12203	-4.16505	-33.84161
Deep	0.0	0.0	0.0
Subtotal	-0.90110	-30.91435	-255.88152
Station Pair 27:	INDOPAC I-57 to INDOPAC I-59		
Surface	0.51292	17.68102	147.46086
California	0.0	0.0	0.0
N. Pac. Central	0.22773	7.82102	64.81224
Intermediate	0.22897	7.80677	64.40781
Subarctic	0.05770	1.92475	16.22656
Deep	-1.66732	-57.78220	-458.03979
Subtotal	-0.64001	-22.54866	-165.13232
Station Pair 28:	INDOPAC I-59 to INDOPAC I-61		
Surface	1.31125	45.15105	376.21484
California	0.0	0.0	0.0
N. Pac. Central	0.70994	24.36292	201.76183
Intermediate	0.94561	32.23195	265.04395
Subarctic	-1.09753	-37.82498	-302.63013
Deep	-0.92162	-31.93069	-253.22672
Subtotal	0.94765	31.99023	287.16357

WATER MASS	MASS	SALT	HEAT
Station Pair 29: INDOPAC I-61 to INDOPAC I-63			
Surface	-3.59019	-123.76407	-1030.72778
California	0.0	0.0	0.0
N. Pac. Central	-2.56340	-88.03937	-729.50342
Intermediate	-1.74764	-59.58736	-490.03564
Subarctic	5.29578	182.77779	1458.89746
Deep	6.88757	238.70728	1892.11670
Subtotal	4.28212	150.09427	1100.74731
Station Pair 30: INDOPAC I-63 to INDOPAC I-65			
Surface	-0.15224	-5.26284	-43.87347
California	0.0	0.0	0.0
N. Pac. Central	0.24923	8.56761	71.02879
Intermediate	0.21326	7.26891	59.78746
Subarctic	-2.15779	-74.54037	-594.12646
Deep	-3.69741	-128.15607	-1015.80859
Subtotal	-5.54495	-192.12274	-1522.99194
Station Pair 31: INDOPAC I-65 to INDOPAC I-66			
Surface	-1.83890	-63.62831	-530.48462
California	0.0	0.0	0.0
N. Pac. Central	-1.34018	-46.16931	-383.43848
Intermediate	-0.37616	-12.85046	-106.00470
Subarctic	0.56353	19.49954	155.01086
Deep	1.14305	39.60867	314.07666
Subtotal	-1.84865	-63.53987	-550.84009
Station Pair 32: INDOPAC I-66 to INDOPAC I-67			
Surface	0.60493	20.94135	174.57314
California	0.0	0.0	0.0
N. Pac. Central	0.16283	5.60705	46.54575
Intermediate	0.12362	4.22784	34.89668
Subarctic	0.0	0.0	0.0
Deep	0.0	0.0	0.0
Subtotal	0.89138	30.77621	256.01538

WATER MASS	MASS	SALT	HEAT
Station Pair 33:	INDOPAC I-67	to INDOPAC I-68	
Surface	4.10387	141.81090	1180.00439
California	0.0	0.0	0.0
N. Pac. Central	3.03907	104.48322	865.98193
Intermediate	0.33748	11.52778	95.05159
Subarctic	0.0	0.0	0.0
Deep	0.0	0.0	0.0
Subtotal	7.48042	257.82178	2141.03784
Station Pair 34:	INDOPAC I-68	to INDOPAC I-69	
Surface	-4.58801	-158.58734	-1320.50317
California	0.0	0.0	0.0
N. Pac. Central	-2.83762	-97.63135	-809.27686
Intermediate	-1.76620	-60.25754	-495.57324
Subarctic	5.55132	190.80193	1533.72778
Deep	0.0	0.0	0.0
Subtotal	-3.64050	-125.67412	-1091.62549
Station Pair 35:	INDOPAC I-69	to INDOPAC I-71	
Surface	-4.82213	-167.00636	-1393.22656
California	0.0	0.0	0.0
N. Pac. Central	-5.50619	-189.97359	-1578.02490
Intermediate	-1.89416	-64.66539	-533.55200
Subarctic	9.59420	331.03271	2643.99854
Deep	39.68202	1375.90967	10899.85938
Subtotal	37.05374	1285.29712	10039.05078
Station Pair 36:	INDOPAC I-71	to INDOPAC I-73	
Surface	1.84924	64.05840	534.57837
California	0.0	0.0	0.0
N. Pac. Central	2.67256	92.23613	766.52148
Intermediate	0.61233	20.89281	172.75806
Subarctic	-4.50899	-155.43121	-1243.47095
Deep	-17.34517	-601.41431	-4764.63672
Subtotal	-16.72002	-579.65796	-4534.24609

WATER MASS	MASS	SALT	HEAT
Station Pair 37:	INDOPAC I-73 to INDOPAC I-75		
Surface	8.43444	291.74780	2429.15039
California	0.0	0.0	0.0
N. Pac. Central	5.91585	203.59259	1689.28101
Intermediate	4.15967	141.97418	1168.25537
Subarctic	-14.51854	-501.29492	-3999.28662
Deep	-63.79919	-2212.35474	-17524.32422
Subtotal	-59.80775	-2076.33496	-16236.92578
Station Pair 38:	INDOPAC I-75 to INDOPAC I-77		
Surface	1.51764	52.33044	434.32910
California	0.0	0.0	0.0
N. Pac. Central	0.43191	14.81273	122.57652
Intermediate	0.64522	21.98192	180.62511
Subarctic	0.10020	3.47288	27.53091
Deep	-0.07688	-2.69718	-21.00049
Subtotal	2.61809	89.90077	744.06104
Station Pair 39:	INDOPAC I-77 to INDOPAC I-79		
Surface	-2.20712	-76.18704	-632.65112
California	0.0	0.0	0.0
N. Pac. Central	-0.56838	-19.51607	-161.55385
Intermediate	-0.61128	-20.83438	-171.44650
Subarctic	1.46353	50.52914	403.10132
Deep	8.97609	311.15283	2465.52759
Subtotal	7.05283	245.14449	1902.97778
Station Pair 40:	INDOPAC I-79 to INDOPAC I-81		
Surface	-6.67943	-231.41876	-1926.17139
California	0.0	0.0	0.0
N. Pac. Central	-4.72938	-162.93047	-1352.38696
Intermediate	-3.07051	-104.74426	-861.50024
Subarctic	8.57957	296.11401	2363.65771
Deep	21.72964	753.26099	5968.82031
Subtotal	15.82988	550.28149	4192.41797

WATER MASS	MASS	SALT	HEAT
Station Pair 41:	INDOPAC I-81 to INDOPAC I-83		
Surface	10.39897	358.80591	2941.84790
California	0.0	0.0	0.0
N. Pac. Central	0.0	0.0	0.0
Intermediate	24.89851	856.97339	7016.69141
Subarctic	-10.72767	-370.34082	-2955.11108
Deep	-30.79559	-1067.64014	-8459.19922
Subtotal	-6.22578	-222.20166	-1455.77344
Station Pair 42:	INDOPAC I-83 to INDOPAC I-85		
Surface	0.0	0.0	0.0
California	0.0	0.0	0.0
N. Pac. Central	0.0	0.0	0.0
Intermediate	-11.13165	-381.63599	-3115.13086
Subarctic	-4.12278	-142.34567	-1135.55542
Deep	-24.12177	-836.32788	-6625.86719
Subtotal	-39.37619	-1360.30933	-10876.55078
Station Pair 43:	INDOPAC I-85 to INDOPAC I-87		
Surface	-11.86495	-409.72852	-3400.62207
California	0.0	0.0	0.0
N. Pac. Central	-6.53071	-224.34108	-1857.78955
Intermediate	-6.98588	-239.04507	-1963.00635
Subarctic	14.80660	511.36450	4077.65576
Deep	63.90004	2215.72534	17551.91406
Subtotal	53.32509	1853.97510	14408.15234
Station Pair 44:	INDOPAC I-87 to INDOPAC I-89		
Surface	9.55035	330.52783	2746.96289
California	0.0	0.0	0.0
N. Pac. Central	6.79643	233.66109	1936.22144
Intermediate	4.32764	147.81053	1214.24023
Subarctic	-9.77676	-337.52832	-2693.31445
Deep	-40.78888	-1414.39648	-11204.49609
Subtotal	-29.89122	-1039.92578	-8000.38672

WATER MASS	MASS	SALT	HEAT
Station Pair 45:	INDOPAC I-89 to	INDOPAC I-91	
Surface	-7.88103	-272.73291	-2273.40381
California	0.0	0.0	0.0
N. Pac. Central	-3.76135	-129.32088	-1072.31372
Intermediate	-3.50387	-119.56943	-982.67749
Subarctic	5.35035	184.74051	1473.73755
Deep	18.51855	642.15063	5086.82813
Subtotal	8.72266	305.26807	2232.17065
Station Pair 46:	INDOPAC I-91 to	INDOPAC I-92	
Surface	7.14235	247.48308	2067.33813
California	0.0	0.0	0.0
N. Pac. Central	3.73588	128.50659	1065.16919
Intermediate	3.37432	114.92603	945.06250
Subarctic	-5.24007	-180.82317	-1443.35498
Deep	-86.58156	-3002.55469	-23777.21484
Subtotal	-77.56908	-2692.46240	-21143.00000
Station Pair 47:	INDOPAC I-92 to	INDOPAC I-93	
Surface	3.87459	133.53107	1111.29102
California	0.0	0.0	0.0
N. Pac. Central	0.0	0.0	0.0
Intermediate	3.13753	106.86459	877.43457
Subarctic	-1.61226	-55.77979	-443.46289
Deep	34.45474	1195.03198	9461.60156
Subtotal	39.85460	1379.64771	11006.86328
Station Pair 48:	INDOPAC I-93 to	INDOPAC I-95	
Surface	-18.99075	-655.46924	-5457.36719
California	0.0	0.0	0.0
N. Pac. Central	-15.83830	-544.68604	-4507.46484
Intermediate	-5.69382	-195.17429	-1606.75391
Subarctic	25.31216	874.03882	6970.69922
Deep	106.26227	3684.56909	29188.91016
Subtotal	91.05156	3163.27832	24588.02344

WATER MASS	MASS	SALT	HEAT
Station Pair 49:	INDOPAC I-95 to INDOPAC I-97		
Surface	3.15826	109.74318	916.96631
California	0.0	0.0	0.0
N. Pac. Central	4.66232	161.41829	1342.42090
Intermediate	-0.24304	-8.41105	-65.71400
Subarctic	-7.80389	-269.25635	-2150.21167
Deep	-31.66768	-1098.02466	-8699.39453
Subtotal	-31.89403	-1104.53052	-8655.92969

APPENDIX D

CARD IMAGE FORMAT

MASTER CARD

CARD COL.	VARIABLE
1- 2	SHIP CODE (WT)
3- 4	LATITUDE (DEGREES)
5- 6	LATITUDE (MINUTES)
7	LATITUDE (TENTHS OF MINUTES)
8	HEMISPHERE (N OR S)
9-11	LONGITUDE (DEGREES)
12-13	LONGITUDE (MINUTES)
14	LONGITUDE (TENTHS OF MINUTES)
15	HEMISPHERE (E OR W)
16-17	YEAR
18-19	MONTH
20-21	DAY
22-23	HOUR (GMT) } FIRST CAST
24-25	MINUTES (GMT) } FIRST CAST
26-27	HOUR (GMT } SECOND CAST
28-29	MINUTES (GMT } SECOND CAST
30-34	SOUNDING (M), i.e. depth in meters
35	IF BLANK, SOUNDING IN METERS IF =1, SOUNDING IN FATHOMS
36-37	WAVE DIRECTION
38-39	WAVE HEIGHT (FEET)
40-41	WAVE PERIOD (SECONDS)
42-43	WIND DIRECTION
44-45	WIND FORCE (KNOTS)
46-49	BAROMETER
50	IF BLANK, BAROMETER IN MILLIBARS IF =1, BAROMETER IN INCHES
51-53	DRY BULB } AIR TEMPERATURE
54-56	WET BULB } AIR TEMPERATURE
57	IF BLANK, AIR TEMPERATURE IN °C IF =1, AIR TEMPERATURE IN °F
58	WEATHER
59	CLOUD TYPE
60	CLOUD AMOUNT
61	VISIBILITY
62-63	WATER COLOR
64-65	WATER TRANSPARENCY
66	
67-69	CRUISE NAME OR NUMBER
70-73	NODC ASSIGNED CRUISE NUMBER
74-79	STATION NUMBER
80	ALWAYS 1 FOR MASTER CARD

DATA CARD

CARD COL.	VARIABLE
1- 5	DEPTH (M) (I5)
6	DEPTH FOOTNOTE INDICATOR
7-11	TEMPERATURE (°C) (F5.3)
12	TEMPERATURE FOOTNOTE INDICATOR
13	TEMPERATURE ACCURACY INDICATOR: 1 = TEMP GOOD TO 1 DECIMAL PLACE 2 = TEMP GOOD TO 2 DECIMAL PLACES 3 = TEMP GOOD TO 3 DECIMAL PLACES
14-18	SALINITY (°/oo) (F5.3)
19	SALINITY FOOTNOTE INDICATOR
20	SALINITY ACCURACY INDICATOR: 1 = SAL GOOD TO 1 DECIMAL PLACE 2 = SAL GOOD TO 2 DECIMAL PLACES 3 = SAL GOOD TO 3 DECIMAL PLACES
21-23	OXYGEN (mℓ/ℓ) (F3.2)
24	OXYGEN FOOTNOTE INDICATOR
25	1 = OXYGEN > 9.99
26-28	PO_4 (mℓ/ℓ) (F3.2)
29	PO_4 FOOTNOTE INDICATOR
30-33	SILICATE (µg at/ℓ) (F4.1)
34-36	NITRITE (µg at/ℓ) (F3.2)
37	NITRITE FOOTNOTE INDICATOR
38-40	NITRATE (µg at/ℓ) (F3.1)
41	NITRATE FOOTNOTE INDICATOR
42-66	
67-69	CRUISE NAME OR NUMBER
70-73	NODC ASSIGNED CRUISE NUMBER
74-79	STATION NUMBER
80	ALWAYS 3, 4 OR 5 FOR DATA CARD

FOOTNOTE CARD

CARD COL.	VARIABLE
1-64	FOOTNOTE INFORMATION
67-69	CRUISE NAME OR NUMBER
70-73	NODC ASSIGNED CRUISE NUMBER
74-79	STATION NUMBER
80	ALWAYS 7 FOR FOOTNOTE CARD

APPENDIX E

KEY COMPUTER VARIABLE DEFINITIONS

ADH	-	dynamic height at station A
AHEATT	-	absolute heat transport (10^{12} cal/sec)
AMASST	-	absolute mass transport (10^{12} gm/sec)
AMB	-	dynamic height at station A minus dynamic height at station B
ASALTT	-	absolute salt transport (10^{12} gm/sec)
AVDENS	-	average density in grams/cubic centimeter
AVSAL	-	average salinity in $^{0}/oo$
AVT	-	absolute volume transport
AVTEMP	-	average absolute temperature in degrees Kelvin
BDH	-	dynamic height at station B
BSVA	-	interpolated values of temperature in degrees centigrade
D	-	actual depth levels of oceanographic cast in meters
DD	-	interpolated values of dynamic height
DH	-	interpolated values of mean specific volume anomaly
ICOUNT	-	iteration counter for linear interpolation method for determining level of no motion
INSTA	-	number of oceanographic stations to be considered
IO,IT,IS	-	information character on oxygen, temperature, and salinity, respectively
KLNM	-	desirability indicator for level of no motion determination
LNM	-	level of no motion
NGC	-	number of geostrophic transports and currents to be calculated; equal to number of station pairs; equal to INSTA-1
NOV	-	number of depths for which information was obtained on that cast
NPA,NPB	-	station pair number at A and B respectively; not to be confused with oceanographic cruise station number; NPA and NPB are initially set as 01 and 02, then 02 and 03, etc.
NSD	-	maximum number of standard depths
OLNM3	-	old level of no motion number 3
O2	-	actual oxygen at level of oceanographic cast in $m\ell/\ell$
RVEL	-	relative velocity in cm/sec
S	-	actual salinity at levels of oceanographic cast in $^{0}/oo$
SGP	-	sigma-t value
SGT	-	interpolated values of sigma-t
SLEV	-	standard level

SQUARE	-	number of previously calculated square areas between deepest common standard depth and bottom; used in calculating bottom area contributions
SS	-	interpolated values of salinity in $^{o}/oo$
SSUM	-	cumulative total of absolute salt transport (10^{12} gm/sec)
ST	-	interpolated values of temperature in degrees centigrade
STD,SD	-	standard depths (interpolated values)
SV	-	interpolated values of specific volume
SVA	-	interpolated values of specific volume anomaly
T	-	actual temperature at levels of oceanographic cast in degrees centigrade
TEMSUM	-	cumulative total of absolute heat transport (10^{12} cal/sec)
VEL	-	absolute velocity in cm/sec
XMSUM	-	cumulative total of absolute mass transport (10^{12} gm/sec)
Z	-	depth in meters

APPENDIX F

COMPUTER PROGRAM

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C THIS FROGRAM WAS ORIGINALLY WRITTEN BY THE DEPARTMENT OF OCEANOGRAPHY OF THE
C U.S. NAVAL POSTGRADUATE SCHOOL, MONTEREY, CA. AND ENTITLED 'HYDRO.'  IT HAS
C BEEN SUBSEQUENTLY MODIFIED TO A LARGE EXTENT BY THE MASTER'S THESES OF GREESON
C (1974), MASON (1978), AND WHITFORD (1979).  THIS PROGRAM INPUTS OCEANOGRAPHIC
C STATION DATA (TEMP., SALINITY, AND DEPTH), INTERPOLATES THE DATA TO STANDARD
C DEPTHS, CALCULATES RELATIVE AND ABSOLUTE GEOSTROPHIC CURRENTS, IDENTIFIES
C WATER MASSES, AND CALCULATES MASS, SALT, AND HEAT TRANSPORTS.  THE OPERATOR
C MAY EITHER SPECIFY A LEVEL OF NO MOTION (LNM) OR HE MAY HAVE THE PROGRAM
C CALCULATE IT FOR HIM.  SEE APPENDIX A OF WHITFORD (1979) N.P.S. MASTER'S
C THESIS FOR JOB CONTROL LANGUAGE (JCL) REQUIRED.
      REAL LNM,LNM1,LNM2,LNM3
      REAL *8 ITL(12),INFO(30,8)
      DIMENSION STD(60)
      DIMENSION SQUARE (55)
      DIMENSION Z(60),VEL(60)
      DIMENSION IT(50),IS(50),IO(50)
      DIMENSION D(50),T(50),S(50),O2(50),ADD(60),BDD(60)
      DIMENSION SD(60),ST(60),SS(60),SGT(60),SV(60),SVA(60)
      DIMENSION SGP(60),DH(60),BDH(60),DD(55,60),SLEV(55),BSVA(60)
      DIMENSION NPA(55),NPB(55),NO(55),NSTA(55,3),ALT(98),ALM(55)
      DIMENSION ALN(55),ANM(55),IDATE(55,3),DHT(55,60),ADH(60)
      DIMENSION XDENS(60,55),XSAL(60,55),XTEMP(60,55),YDE(60,55)
      DIMENSION YTT(60,55),YSL(60,55),TEMSUM(60),XMSUM(60),SSUM(60)
    3 FORMAT (1H1,'STATION,',3A4,' LATITUDE ',I2,F5.1,'N LONGITUDE ',
     1I4,F5.1,'E  DATE ',3A4/5X,' TO,',3A4,' LATITUDE ',I2,F5.1,
     2'N LONGITUDE ',I4,F5.1,'E  DATE ',3A4//)
    8 FORMAT (1H1,'STATION,',3A4,' LATITUDE ',I2,F5.1,'N LONGITUDE ',
     1I4,F5.1,'W  DATE ',3A4/5X,' TO,',3A4,' LATITUDE ',I2,F5.1,
     2'N LONGITUDE ',I4,F5.1,'W  DATE ',3A4//)
    9 FORMAT (16(1X,2I2))
   10 FORMAT(1H1,'STATION ',3A4,'  LATITUDE = ',I2,F5.1,'N LONGITUDE =',
     1I4,F5.1,'W  DATE ',3A4//)
   11 FORMAT(1H1,'STATION ',3A4,'  LATITUDE = ',I2,F5.1,'N LONGITUDE =',
     1I4,F5.1,'E  DATE ',3A4//)
   12 FORMAT(10X,'* INDICATES ADJUSTED VALUE')
   13 FORMAT(I5,3A4,F3.0,2F5.1,F4.1,3A4)
   15 FORMAT(F9.0,F10.2,1X,A1,F9.3,A1,F8.2,A1,8X,4A8)
   16 FORMAT(10X,'DEPTH  TEMPERATURE  SALINITY  SIGMA-T  OXYGEN'//)
   17 FORMAT(20X,'OBSERVED VALUES'//)
   18 FORMAT(//20X,'INTERPOLATED VALUES'//)
   19 FORMAT(10X,'DEPTH  TEMPERATURE  SALINITY  SIGMA-T   SPEC VOL  SPEC
     1 V ANOM  MEAN SVA   DELTA D   DYNAMIC HEIGHT'//)
   20 FORMAT(10X,F5.0,F10.2,F12.3,F9.3,F11.4,F13.6,23X,F12.5/70X,F11.6,F
     111.5)
   21 FORMAT(10X,F5.0,F10.2,A1,F11.3,A1,F8.3,F9.2,A1,4X,4A8/)
      DATA SD/0.,50.,100.,150.,200.,250.,300.,350.,400.,450.,500.,550.,
     1600.,650.,700.,750.,800.,851.,900.,950.,1000.,1050.,1100.,1150.,
     21200.,1250.,1300.,1400.,1500.,1600.,1700.,1800.,1900.,2000.,
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     32250.,2500.,2750.,3000.,3250.,3500.,3750.,4000.,4250.,4500.,4750.,
     45000.,5250.,5500.,5750.,6000./
      ICOUNT=0
      OLNM3=0.
C
C  MAX NUMBER OF STANDARD DEPTHS IS NSD
      NSD=50
      DO 9050 I=1,NSD
      STD(I)=SD(I)
 9050 CONTINUE
C
C NUMBER OF STATIONS TO BE CONSIDERED IS INSTA
      INSTA=50
C
C NGC IS THE NUMBER OF GEOSTROPHIC CURRENTS AND TRANSPORTS TO BE CALCULATED.
C THUS, IT IS ALSO EQUAL TO THE NUMBER OF STATION PAIRS.  IF YOU SET NGC=0
C VICE 'INSTA-1', YOU WILL PRODUCE A PRINTOUT OF JUST YOUR INPUT DATA AND
C NOT DYNAMIC HEIGHT OF TRANSPORT CALCULATIONS.
      NGC=INSTA-1
      IF(NGC.EQ.0) GO TO 410
      READ(5,50)(SQUARE(I),I=1,NGC)
   50 FORMAT(16F5.1)
      READ (5,9) (NPA(I),NPB(I),I=1,NGC)
  410 NPA(NGC+1)=0
C IF IT IS DESIRED TO UTILIZE THE COMPUTER TO DETERMINE THE LNM (LEVEL OF NO
C MOTION), SET KLNM=1 AND CHOSE A SHALLOW ESTIMATE OF THE LNM FOR LNM1 AND A
C DEEP ESTIMATE FOR LNM2.  TO SAVE UNNECESSARY PRINTING, SET ALL WRITE
C STATEMENTS (EXCEPT 9016 AND 9022) TO A DUMMY 8 VICE A PRINT 6.  IF NOT DESIRED
C ,SET KLNM=0,INPUT A SELECTED LNM AT STATEMENT 667, AND INSURE THAT THE
C SELECTED LNM IS A STANDARD DEPTH LEVEL (SD).
      LNM1=750.
      LNM2=1500.
   22 DO 2000 I=1,60
      XMSUM(I)=0.
      TEMSUM(I)=0.
      SSUM(I)=0.
 2000 CONTINUE
      KLNM=0
      IF(KLNM.EQ.0) GO TO 667
      ICOUNT=ICOUNT+1
      IF(ICOUNT.EQ.1) LNM=LNM1
      IF(ICOUNT.EQ.2) LNM=LNM2
      IF(ICOUNT.GE.3) LNM=LNM3
  667 IF ((ICOUNT.EQ.0). AND .(KLNM.EQ.0)) LNM=851.
      DO 777 I=1,NGC
      SLEV(I)=LNM
  777 CONTINUE
      DO 4 I=1,NSD
```

```
    4 Z(I)=-SD(I)
      DC 41 L=1,INSTA
C
C          READ HEADING CARD, CHECK FOR  END OF DATA, THEN
C          READ NOV DATA CARDS.
C
      READ (1,13,END=32) NOV,(NSTA(L,K),K=1,3),ALT(L),ALM(L),ALN(L),
     1ANM(L),(IDATE(L,K),K=1,3)
      IF (NOV) 32,32,24
   24 DO 25 I=1,NOV
      READ (1,15) D(I),T(I),IT(I),S(I),IS(I),O2(I),IO(I),
     1(INFO(I,J),J=1,4)
C
C          SGTSVA IS SUBROUTINE TO COMPUTE SIGMA-T, SPECIFIC VOLUME
C          AND SPECIFIC VOLUME ANOMALY.
C
   25 CALL SGTSVA (T(I),S(I),D(I),SGP(I),SVNO,SVNO)
C
C          LGTP IS SUBROUTINE TO COMPUTE INTERPOLATED VALUES
C
      CALL LGTP(NOV,D,T,NSD,SD,ST,NA)
      CALL LGTP(NOV,D,S,NSD,SD,SS,NB)
      NO(L)=NA
      DO 27 I=1,NA
      CALL SGTSVA (ST(I),SS(I),SD(I),SGT(I),SV(I),SVA(I))
   27 CONTINUE
      DO 2500 I=1,NA
      XDENS(I,L)=1./SV(I)
      XTEMP(I,L)=ST(I)+273.15
      XSAL(I,L)=SS(I)
 2500 CONTINUE
      II=NA-1
      DO 2510 I=1,II
      YDE(I,L)=(XDENS(I,L)+XDENS(I+1,L))*.5
      YTT(I,L)=(XTEMP(I,L)+XTEMP(I+1,L))*.5
      YSL(I,L)=(XSAL(I,L)+XSAL(I+1,L))*.5
 2510 CONTINUE
      NLT=ALT(L)
      NLN=ALN(L)
      IF (NLN.LT.0) GO TO 34
      WRITE (8,10) (NSTA(L,K),K=1,3),NLT,ALM(L),NLN,ANM(L),
     1(IDATE(L,K),K=1,3)
      GO TO 37
   34 NNLN= IABS(NLN)
   35 WRITE (8,11) (NSTA(L,K),K=1,3),NLT,ALM(L),NNLN,ANM(L),
     1(IDATE(L,K),K=1,3)
   37 WRITE (8,17)
      WRITE (8,16)
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      DC 29 I=1,NOV
   29 WRITE (8,21) D(I),T(I),IT(I),S(I),IS(I),SGP(I),O2(I), IO(I),
     1(INFO(I,J),J=1,4)
      WRITE(8,12)
      WRITE (8,18)
      WRITE (8,19)
      NA=NA-1
      DH(1)=0.
      DO 30 I=1,NA
      BSVA(I)=(SVA(I)+SVA(I+1))*.5
      DD(L,I)=BSVA(I)*(SD(I+1)-SD(I))
   30 DH(I+1)=DH(I)+DD(L,I)
      DO 31 I=1,NA
      DHT(L,I)=DH(I)
   31 WRITE (8,20) SD(I),ST(I),SS(I),SGT(I),SV(I),SVA(I),DH(I),
     1BSVA(I),DD(L,I)
      I=NA+1
      DHT(L,I)=DH(I)
      WRITE (8,20) SD(I),ST(I),SS(I),SGT(I),SV(I),SVA(I),DH(I)
   41 CONTINUE
   32 IF(NGC.EQ.0) GO TO 33
      DO 42 L=1,INSTA
      IF (NPA(L).EQ.0) GO TO 3999
      BASE=SLEV(L)
      N1=NPA(L)
      N2=NPB(L)
      NU1=NO(N1)
      NU2=VO(N2)
      DO 43 I=1,NU1
      ADD(I)=DD(N1,I)
   43 ADH(I)=DHT(N1,I)
      DO 44 I=1,NU2
      BDD(I)=DD(N2,I)
   44 BDH(I)=DHT(N2,I)
      NLT=ALT(N1)
      NLN=ALN(N1)
      MLT=ALT(N2)
      MLN=ALN(N2)
      IF(NLN.LT.0) GO TO 490
      WRITE (8,8) (NSTA(N1,K),K=1,3),NLT,ALM(N1),NLN,ANM(N1),
     1(IDATE(N1,K),K=1,3),(NSTA(N2,K),K=1,3),MLT,ALM(N2),MLN,
     2ANM(N2),(IDATE(N2,K),K=1,3)
      GO TO 498
  490 NNLN=IABS(NLN)
      MMLN=IABS(MLN)
      WRITE (8,3) (NSTA(N1,K),K=1,3),NLT,ALM(N1),NNLN,ANM(N1),
     1(IDATE(N1,K),K=1,3),(NSTA(N2,K),K=1,3),MLT,ALM(N2),MMLN,
     2ANM(N2),(IDATE(N2,K),K=1,3)
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  498 ALAT=ALT(N1)+ALM(N1)/60.
      BLAT=ALT(N2)+ALM(N2)/60.
      IF(ALN(N1).LT.0.) GO TO 500
      ALON=ALN(N1)+ANM(N1)/60.
      GO TO 502
  500 ALON=ALN(N1)-ANM(N1)/60
  502 IF(ALN(N2).LT.0.) GO TO 501
      BLON=ALN(N2)+ANM(N2)/60.
      GO TO 503
  501 BLON=ALN(N2)-ANM(N2)/60
  503 CALL DSTSTA (ALAT,ALON,BLAT,BLON,X2,DIST)
      CALL GEOCUR (NU1,ADH,NU2,BDH,SD,BASE,X2,VEL,NNN,DIST,YDE,YTT,YSL,
     1XMSUM,TEMSUM,SSUM,L,NGC,NSD,SQUARE)
   42 CONTINUE
 3999 TSSUM=0.0
      THSUM=0.0
      TMSUM=0.0
      WRITE (8,6002)
 6002 FORMAT (///20X,'DEPTH',10X,'TOTAL MASS',10X,'TOTAL SALT',10X,'TOTA
     1L HEAT'/35X,'TRANSPORT',11X,'TRANSPORT',11X,'TRANSPORT')
C MAX NUMBER OF STANDARD DEPTHS MINUS ONE IS NSDM1
      NSDM1=NSD-1
      DO 5000 J=1,NSDM1
      TMSUM=TMSUM+XMSUM(J)
      THSUM=THSUM+TEMSUM(J)
      TSSUM=TSSUM+SSUM(J)
      WRITE (8,6003) J, SD(J),XMSUM(J),SSUM(J),TEMSUM(J)
 6003 FORMAT ('0',10X,I4,6X,F5.0/29X,E16.6,4X,E16.6,4X,E16.6)
 5000 CONTINUE
      IX=NSD
      WRITE (8,6003) IX,SD(IX)
      WRITE (8,6004)
 6004 FORMAT (' ',37X,'---------',12X,'---------',12X,'---------')
      WRITE(8,7000)
 7000 FORMAT('0',16X,'SUBTOTAL')
      WRITE (8,6001) TMSUM,TSSUM,THSUM
 6001 FORMAT ('+',29X,E16.6,4X,E16.6,4X,E16.6)
      WRITE(8,7001) XMSUM(IX),SSUM(IX),TEMSUM(IX)
 7001 FORMAT (///14X,'BOTTOM AREA',5X,E16.6,4X,E16.6,4X,E16.6/13X,
     *'CONTRIBUTION')
      TMSUM=TMSUM+XMSUM(IX)
      TSSUM=TSSUM+SSUM(IX)
      THSUM=THSUM+TEMSUM(IX)
      WRITE(8,6004)
      WRITE(8,7002)
 7002 FORMAT('0',13X,'GRAND TOTAL')
      WRITE (8,6001) TMSUM,TSSUM,THSUM
      IF((ICOUNT.EQ.0). OR .(KLNM.EQ.0)) GO TO 33
```

```
9010 IF(ICOUNT.EC.25) GO TO 9022
     TOLER1=ABS(LNM2-LNM1)
     REWIND 1
     IF(TOLER1.LE.1.0) GO TO 9022
C IF IT IS DESIRED TO DETERMINE LNM VIA A SALT OR HEAT TRANSPORT OF ZERO,
C SUBSTITUTE TSSUM OR THSUM FOR ALL VARIATIONS OF TMSUM FROM THIS POINT TO
C THE END OF THE MAIN PROGRAM.
     IF(ICOUNT.EQ.1) TMSUM1=TMSUM
     IF(ICOUNT.EQ.1) GO TO 22
     IF(ICOUNT.EQ.2) TMSUM2=TMSUM
     IF(ICOUNT.EQ.2) GO TO 9020
     IF(ICOUNT.GE.3) TMSUM3=TMSUM
     B=TMSUM3*TMSUM1
     IF(B.LT.0.0) GO TO 9014
     LNM1=LNM3
     TMSUM1=TMSUM3
     GO TO 9016
9014 LNM2=LNM3
     TMSUM2=TMSUM3
9016 WRITE (8,9018) TMSUM,LNM,ICOUNT
9018 FORMAT (10X,'TOTAL MASS TRANSPORT= ',E16.6,' FOR LNM= ',F6.0,' AND
    * ITERATIONS= ',I2)
C
C METHOD OF LINEAR INTERPOLATION  (REGULA FALSI METHOD)
9020 LNM3= LNM2 - TMSUM2 * ((LNM2 - LNM1)/(TMSUM2 - TMSUM1))
C
     LNM3=LNM3+0.5
     LLNM3=IFIX(LNM3)
     LNM3=FLOAT(LLNM3)
     TOLER2=ABS(OLNM3-LNM3)
     IF(TOLER2.LE.0.9) GO TO 9022
     OLNM3=LNM3
     DO 9053 I=1,NSD
9053 SC(I)=STO(I)
     DO 9055 I=1,NSD
     IF((LNM3.GE.SD(I)) .AND. (LNM3.LT.SD(I+1)))   SD(I)=LNM3
9055 CONTINUE
     GO TO 22
9022 WRITE (8,9024) TMSUM,LNM,ICOUNT
9024 FORMAT(5X,'FINAL RESULTS:  TOTAL MASS TRANSPORT= ',E16.6,' FOR LNM
    *= ',F6.0,' AND ITERATIONS= ',I2)
     IF(ICOUNT.LT.25) GO TO 33
     WRITE (8,9026)
9026 FORMAT(5X,'PROGRAMMER (DJW) SUGGESTS THAT YOUR CHOICES FOR LNM1 AN
    *D LNM2 ARE NOT BRACKETING THE ACTUAL LNM.  IT IS SUGGESTED THAT YO
    *U RESELECT THEM ACCORDINGLY')
  33 STOP
     END
```

```
      SUBROUTINE LGTP(N,D,V,M,SD,CV,NN)
C THIS SUBROUTINE TAKES ACTUAL DATA FROM VARIOUS DEPTHS AND INTERPOLATES THEM
C TO STANDARD DEPTHS.  IT USES A COMBINATION OF LINEAR AND PARABOLIC MEAN
C INTERPOLATION METHODS.
      DIMENSION D(N),V(N),CV(M),SD(M)
      JJJ=0
  111 DO 188 J=1,M
  112 DC 186 I=1,N
      IF(SD(J)-D(N))113,115,190
  115 CV(J)=V(N)
      JJJ=JJJ+1
      GO TO 190
  113 IF(SD(J)-D(I))114,114,116
  114 CV(J)=V(I)
      GO TO 170
  116 IF(SD(J)-D(I+1))120,118,186
  118 CV(J)=V(I+1)
      GO TO 170
  120 IF(((D(1).LT.SD(J)).AND.(SD(J).LT.D(2))).OR.
     $    ((D(N-1).LT.SD(J)).AND.(SD(J).LT.D(N)))) GO TO 134
      XA=(SD(J)-D(I))*(SD(J)-D(I+1))*V(I-1)/
     1((D(I-1)-D(I))*(D(I-1)-D(I+1)))
      XB=(SD(J)-D(I-1))*(SD(J)-D(I+1))*V(I)/
     1((D(I)-D(I-1))*(D(I)-D(I+1)))
      XC=(SD(J)-D(I-1))*(SD(J)-D(I))*V(I+1)/
     1((D(I+1)-D(I-1))*(D(I+1)-D(I)))
      ANSU=XA+XB+XC
      YA=(SD(J)-D(I+1))*(SD(J)-D(I+2))*V(I)/
     1((D(I)-D(I+1))*(D(I)-D(I+2)))
      YB=(SD(J)-D(I))*(SD(J)-D(I+2))*V(I+1)/
     1((D(I+1)-D(I))*(D(I+1)-D(I+2)))
      YC=(SD(J)-D(I))*(SD(J)-D(I+1))*V(I+2)/
     1((D(I+2)-D(I))*(D(I+2)-D(I+1)))
      ANSD=YA+YB+YC
      CV(J)=(ANSU+ANSD)/2.
      GO TO 170
  134 ZA=(SD(J)-D(I+1))*V(I)/(D(I)-D(I+1))
      ZB=(SD(J)-D(I))*V(I+1)/(D(I+1)-D(I))
      ANSL=ZA+ZB
      CV(J)=ANSL
      GO TO 170
  186 CONTINUE
  170 JJJ=JJJ+1
  188 CONTINUE
  190 NN=JJJ
      RETURN
      END
```

```
      SUBROUTINE GEOCUR (NA,ADH,NB,BDH,SD,BASE,X2,VEL,NNN,DIST,
C THIS SUBROUTINE COMPUTES ABSOLUTE AND RELATIVE GEOSTROPHIC CURRENTS ONCE A
C LEVEL OF NO MOTION IS DETERMINED.  IT ALSO HANDLES WATER MASS IDENTIFICATION
C AND TRANSPORT.
     1YDE,YTT,YSL,XMSUM,TEMSUM,SSUM,L,NGC,NSD,SQUARE)
      REAL INTMAS,INTSLT,INTHT
      DIMENSION SQUARE (55)
      DIMENSION AMASST(60),ASALTT(60),AHEATT(60),XMSUM(60),TEMSUM(60),
     1SSUM(60),YDE(60,55),YTT(60,55),YSL(60,55),AVDENS(60),AVTEMP(60),
     2AVSAL(60)
      DIMENSION ADH(60),BDH(60),SD(60),RVEL(60),VEL(60),AMB(60),AVT(60)
   10 FORMAT (13X,'DEPTH     DYN HT    DYN HT     DIFF HT   REL VEL    ABS V
     1EL    AVERAGE     AVERAGE ABS      AVERAGE'/15X,'M         STA A    STA
     2B       B-A        CM/SEC     CM/SEC       DENSITY     TEMPERATURE     SAL
     3INITY'/)
   11 FORMAT (12X,F5.0,2X,3(F9.5,1X),2(F8.2,2X)/67X,F12.5,3X,F10.2,4X,F1
     10.3)
   12 FORMAT ('***** LEVEL OF NO MOTION MUST BE EQUAL TO A STANDARD DEPT
     1H *****')
   14 FORMAT(' ',10X,'TOTAL VOLUME TRANSPORT IS COMPUTED BY SUMMING INCR
     1EMENTAL TRANSPORTS ABOVE LEVEL OF NO MOTION:'//5X,'TOTAL TRANSPORT
     2 PERPENDICULAR TO THE PLANE OF THE STATIONS IS ',F7.3,' SVERDRUPS
     3RELATIVE TO ',F5.0,' METERS')
   15 FORMAT(//'  * VALUES IN THIS COLUMN REPRESENT TRANSPORTS IN LAYER
     1INCREMENTS'//)
   16 FORMAT (//13X,'DEPTH',10X,'ABS VOL',8X,'ABS MASS',7X,'ABS SALT',7X
     1,'ABS HEAT'/15X,'M',12X,'TRANSPORT',6X,'TRANSPORT',6X,'TRANSPORT',
     26X,'TRANSPORT',8X,'MASS',11X,'SALT',11X,'HEAT'/)
   17 FORMAT (12X,F5.0/22X,7(F15.5))
   18 FORMAT ('0',32X,'*',14X,'*',14X,'*',14X,'*',20X,'CUMULATIVE TOTALS
     1')
      IF(L .GT. 1) GO TO 50
      TSFMAS=0.0
      TCLMAS=0.0
      TCNMAS=0.0
      TINMAS=0.0
      TSBMAS=0.0
      TDPMAS=0.0
      TUNMAS=0.0
      TSFSLT=0.0
      TCLSLT=0.0
      TCNSLT=0.0
      TINSLT=0.0
      TSBSLT=0.0
      TDPSLT=0.0
      TUNSLT=0.0
      TSFHT =0.0
      TCLHT =0.0
```

```
      TCNHT =0.0
      TINHT =0.0
      TSBHT =0.0
      TDPHT =0.0
      TUNHT =0.0
   50 CONTINUE
      SFCMAS=0.0
      CALMAS=0.0
      CENMAS=0.0
      INTMAS=0.0
      SUBMAS=0.0
      DEPMAS=0.0
      UNKMAS=0.0
      SFCSLT=0.0
      CALSLT=0.0
      CENSLT=0.0
      INTSLT=0.0
      SUBSLT=0.0
      DEPSLT=0.0
      UNKSLT=0.0
      SFCHT=0.0
      CALHT=0.0
      CENHT=0.0
      INTHT=0.0
      SUBHT=0.0
      DEPHT=0.0
      UNKHT=0.0
      IF(NA.LE.NB) GO TO 51
      N=NB
      GO TO 52
   51 N=NA
   52 DO 53 I=1,N
      AMB(I)=BDH(I)-ADH(I)
      RVEL(I)=AMB(I)*X2
   53 CONTINUE
      DO 54 I=1,NSD
      IF(BASE.EQ.SD(I))GO TO 55
   54 CONTINUE
      WRITE (8,12)
      GO TO 70
   55 NM=I
      IF(NM.GT.N) NM=N
      BASE=SD(NM)
      DO 56 I=1,N
   56 VEL(I)=RVEL(NM)-RVEL(I)
      ABSVEL=VEL(N)
      STMASS=0.0
      STSALT=0.0
```

```
      STHEAT=0.0
      WRITE(8,10)
      DO 600 I=2,N
      J=I-1
      AVDENS(J)=(YDE(J,L)+YDE(J,L+1))*.5
      AVSAL(J)=(YSL(J,L)+YSL(J,L+1))*.5
      AVTEMP(J)=(YTT(J,L)+YTT(J,L+1))*.5
      AVEL=(VEL(I)+VEL(J))*0.005
      AVT(J)=AVEL*DIST*(SD(I)-SD(J))*1.0E-03
      AMASST(J)=AVT(J)*AVDENS(J)
      ASALTT(J)=AMASST(J)*AVSAL(J)
      AHEATT(J)=AMASST(J)*AVTEMP(J)
      XMSUM(J)=XMSUM(J)+AMASST(J)
      SSUM(J)=SSUM(J)+ASALTT(J)
      TEMSUM(J)=TEMSUM(J)+AHEATT(J)
      STMASS=STMASS+AMASST(J)
      STSALT=STSALT+ASALTT(J)
      STHEAT=STHEAT+AHEATT(J)
      IF (I .LT. N) GO TO 141
      XFAC=455100.
      IX=NSD
      AVT(IX)=ABSVEL*SQUARE(L)*XFAC/200.0E06
      AMASST(IX)=AVT(IX)*AVDENS(N-1)
      ASALTT(IX)=AMASST(IX)*AVSAL(N-1)
      AHEATT(IX)=AMASST(IX)*AVTEMP(N-1)
      XMSUM(IX)=XMSUM(IX)+AMASST(IX)
      SSUM(IX)=SSUM(IX)+ASALTT(IX)
      TEMSUM(IX)=TEMSUM(IX)+AHEATT(IX)
      STMASS=STMASS+AMASST(IX)
      STSALT=STSALT+ASALTT(IX)
      STHEAT=STHEAT+AHEATT(IX)
C THIS MODULE IDENTIFIES AND SEPERATES THE VARIOUS WATER MASSES.
  141 IF((AVTEMP(J).LE.293.0) .AND. (AVTEMP(J).GE.282.85) .AND.
     1(AVSAL(J).LE.34.90) .AND. (AVSAL(J).GE.34.075) .AND.
     2(SD(J).LE.150.0))    GO TO 4002
      IF((AVTEMP(J).LE.291.0) .AND. (AVTEMP(J).GE.283.0) .AND.
     1(AVSAL(J).LE.34.90) .AND. (AVSAL(J).GE.34.050)) GO TO 4004
      IF((AVTEMP(J).LE.283.27).AND. (AVTEMP(J).GE.277.0) .AND.
     1(AVSAL(J).LE.34.50) .AND. (AVSAL(J).GE.33.84))GO TO 4006
      IF((AVTEMP(J).LE.277.0) .AND. (AVTEMP(J).GE.275.0) .AND.
     1(AVSAL(J).LE.34.65) .AND. (AVSAL(J).GE.34.00))GO TO 4008
      IF((AVTEMP(J).LE.276.0) .AND. (AVTEMP(J).GE.272.0) .AND.
     1(AVSAL(J).LE.34.70) .AND. (AVSAL(J).GE.34.59))GO TO 4010
      IF((AVTEMP(J).LE.290.00) .AND. (AVTEMP(J).GE.281.00) .AND.
     1(AVSAL(J).LE.34.074) .AND. (AVSAL(J).GE.33.100)) GO TO 4012
 4000 WRITE (8,11) SD(J),ADH(J),BDH(J),AMB(J),RVEL(J),VEL(J),AVDENS(J),
     1AVTEMP(J),AVSAL(J)
      WRITE (8,30)
```

```
   30 FORMAT ('+',109X,'UNKNOWN')
      UNKMAS    =UNKMAS    +AMASST(J)
      UNKHT     =UNKHT     +AHEATT(J)
      UNKSLT    =UNKSLT    +ASALTT(J)
      TUNMAS=TUNMAS+AMASST(J)
      TUNHT=TUNHT+AHEATT(J)
      TUNSLT=TUNSLT+ASALTT(J)
      IF (I .LT. N) GO TO 39
      UNKMAS    =UNKMAS    +AMASST(IX)
      UNKHT     =UNKHT     +AHEATT(IX)
      UNKSLT    =UNKSLT    +ASALTT(IX)
      TUNMAS=TUNMAS+AMASST(IX)
      TUNHT=TUNHT+AHEATT(IX)
      TUNSLT=TUNSLT+ASALTT(IX)
      GO TO 39
 4002 WRITE (8,11) SD(J),ADH(J),BDH(J),AMB(J),RVEL(J),VEL(J),AVDENS(J),
     1AVTEMP(J),AVSAL(J)
      WRITE (8,32)
   32 FORMAT ('+',109X,'SURFACE')
      SFCMAS    =SFCMAS    +AMASST(J)
      SFCHT     =SFCHT     +AHEATT(J)
      SFCSLT    =SFCSLT    +ASALTT(J)
      TSFMAS=TSFMAS+AMASST(J)
      TSFHT=TSFHT+AHEATT(J)
      TSFSLT=TSFSLT+ASALTT(J)
      IF (I .LT. N) GO TO 39
      SFCMAS    =SFCMAS    +AMASST(IX)
      SFCHT     =SFCHT     +AHEATT(IX)
      SFCSLT    =SFCSLT    +ASALTT(IX)
      TSFMAS=TSFMAS+AMASST(IX)
      TSFHT=TSFHT+AHEATT(IX)
      TSFSLT=TSFSLT+ASALTT(IX)
      GO TO 39
 4004 WRITE (8,11) SD(J),ADH(J),BDH(J),AMB(J),RVEL(J),VEL(J),AVDENS(J),
     1AVTEMP(J),AVSAL(J)
      WRITE (8,34)
   34 FORMAT ('+',109X,'N. PAC. CENTRAL')
      CENMAS    =CENMAS    +AMASST(J)
      CENHT     =CENHT     +AHEATT(J)
      CENSLT    =CENSLT    +ASALTT(J)
      TCNMAS=TCNMAS+AMASST(J)
      TCNHT=TCNHT+AHEATT(J)
      TCNSLT=TCNSLT+ASALTT(J)
      IF (I .LT. N) GO TO 39
      CENMAS    =CENMAS    +AMASST(IX)
      CENHT     =CENHT     +AHEATT(IX)
      CENSLT    =CENSLT    +ASALTT(IX)
      TCNMAS=TCNMAS+AMASST(IX)
```

AD-A072 048 NAVAL POSTGRADUATE SCHOOL MONTEREY CA F/G 8/3
MASS, SALT, AND HEAT TRANSPORT BY OCEAN CURRENTS ACROSS 35 DEG --ETC(U)
JUN 79 D J WHITFORD

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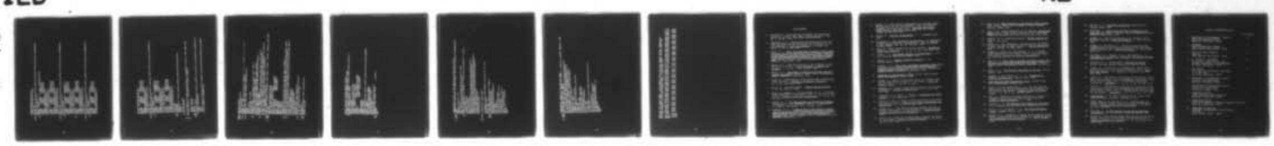

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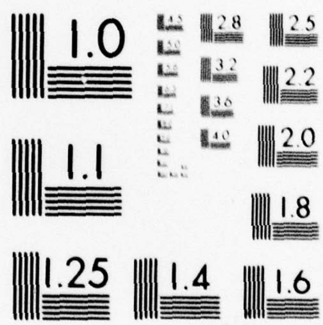

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

```
      TCNHT=TCNHT+AHEATT(IX)
      TCNSLT=TCNSLT+ASALTT(IX)
      GO TO 39
 4006 WRITE (8,11) SD(J),ADH(J),BDH(J),AMB(J),RVEL(J),VEL(J),AVDENS(J),
     1AVTEMP(J),AVSAL(J)
      WRITE (8,36)
   36 FORMAT ('+',109X,'N. PAC. INTERMECIATE')
      INTMAS    =INTMAS    +AMASST(J)
      INTHT     =INTHT     +AHEATT(J)
      INTSLT    =INTSLT    +ASALTT(J)
      TINMAS=TINMAS+AMASST(J)
      TINHT=TINHT+AHEATT(J)
      TINSLT=TINSLT+ASALTT(J)
      IF (I .LT. N) GO TO 39
      INTMAS    =INTMAS    +AMASST(IX)
      INTHT     =INTHT     +AHEATT(IX)
      INTSLT    =INTSLT    +ASALTT(IX)
      TINMAS=TINMAS+AMASST(IX)
      TINHT=TINHT+AHEATT(IX)
      TINSLT=TINSLT+ASALTT(IX)
      GO TO 39
 4008 WRITE (8,11) SD(J),ADH(J),BDH(J),AMB(J),RVEL(J),VEL(J),AVDENS(J),
     1AVTEMP(J),AVSAL(J)
      WRITE (8,38)
   38 FORMAT ('+',109X,'SUBARCTIC')
      SUBMAS    =SUBMAS    +AMASST(J)
      SUBHT     =SUBHT     +AHEATT(J)
      SUBSLT    =SUBSLT    +ASALTT(J)
      TSBMAS=TSBMAS+AMASST(J)
      TSBHT=TSBHT+AHEATT(J)
      TSBSLT=TSBSLT+ASALTT(J)
      IF (I .LT. N) GO TO 39
  752 SUBMAS    =SUBMAS    +AMASST(IX)
      SUBHT     =SUBHT     +AHEATT(IX)
      SUBSLT    =SUBSLT    +ASALTT(IX)
      TSBMAS=TSBMAS+AMASST(IX)
      TSBHT=TSBHT+AHEATT(IX)
      TSBSLT=TSBSLT+ASALTT(IX)
      GO TO 39
 4010 WRITE (8,11) SD(J),ADH(J),BDH(J),AMB(J),RVEL(J),VEL(J),AVDENS(J),
     1AVTEMP(J),AVSAL(J)
      WRITE (8,40)
   40 FORMAT ('+',109X,'DEEP')
      DEPMAS    =DEPMAS    +AMASST(J)
      DEPHT     =DEPHT     +AHEATT(J)
      DEPSLT    =DEPSLT    +ASALTT(J)
      TDPMAS=TDPMAS+AMASST(J)
      TDPHT=TDPHT+AHEATT(J)
```

```
      TDPSLT=TDPSLT+ASALTT(J)
      IF (I .LT. N) GO TO 39
      DEPMAS   =DEPMAS   +AMASST(IX)
      DEPHT    =DEPHT    +AHEATT(IX)
      DEPSLT   =DEPSLT   +ASALTT(IX)
      TDPMAS=TDPMAS+AMASST(IX)
      TDPHT=TDPHT+AHEATT(IX)
      TDPSLT=TDPSLT+ASALTT(IX)
      GO TO 39
4012 WRITE (8,11) SD(J),ADH(J),BDH(J),AMB(J),RVEL(J),VEL(J),AVDENS(J),
    1AVTEMP(J),AVSAL(J)
      WRITE (8,42)
   42 FORMAT ('+',109X,'CALIFORNIA')
      CALMAS   =CALMAS   +AMASST(J)
      CALHT    =CALHT    +AHEATT(J)
      CALSLT   =CALSLT   +ASALTT(J)
      TCLMAS=TCLMAS+AMASST(J)
      TCLHT=TCLHT+AHEATT(J)
      TCLSLT=TCLSLT+ASALTT(J)
      IF (I .LT. N) GO TO 39
      CALMAS   =CALMAS   +AMASST(IX)
      CALHT=    CALHT    +AHEATT(IX)
      CALSLT=   CALSLT+   ASALTT(IX)
      TCLMAS=TCLMAS+AMASST(IX)
      TCLHT=TCLHT+AHEATT(IX)
      TCLSLT=TCLSLT+ASALTT(IX)
      GO TO 39
   39 CONTINUE
  600 CONTINUE
      WRITE(8,11) SD(N),ADH(N),BDH(N),AMB(N),RVEL(N),VEL(N)
      NM=NM-1
      VT=0.
      DO 57 I=1,NM
   57 VT=VT+AVT(I)
C
C     IF STATION B IS EAST OF STATION A, A NEGATIVE SIGN IN THE "ABS VEL"
C     COLUMN IMPLIES A SOUTHWARD FLOWING CURRENT.
C
      WRITE (8,16)
      WRITE (8,18)
   58 N=N-1
8074 DO 62 I=1,N
   62 WRITE (8,17) SD(I),AVT(I),AMASST(I),ASALTT(I),AHEATT(I),XMSUM(I),S
    1SUM(I),TEMSUM(I)
      N=N+1
      I=N
      WRITE (8,17) SD(I),AVT(IX),AMASST(IX),ASALTT(IX),AHEATT(IX),XMSUM
    *(IX),SSUM(IX),TEMSUM(IX)
```

```
8088 WRITE(8,1005)
1005 FORMAT( 11X,'BOTTOM')
     WRITE (8,1001)
1001 FORMAT (' ',41X,'-----------',4X,'-----------',4X,'-----------')
     WRITE (8,1000) STMASS,STSALT,STHEAT
1000 FORMAT('0',11X,'NET TOTALS',15X,3(F15.5))
     NNN=N
     WRITE(8,15)
     WRITE (8,14) VT,BASE
     WRITE(8,109)
 109 FORMAT(//13X,' TRANSPORTS BY WATER MASS TYPE')
     WRITE(8,110)SFCMAS,SFCSLT,SFCHT,
    *CALMAS,CALSLT,CALHT,CENMAS,CENSLT,CENHT,INTMAS,
    1INTSLT,INTHT,SUBMAS,SUBSLT,SUBHT,DEPMAS,DEPSLT,DEPHT,
    2UNKMAS,UNKSLT,UNKHT
 110 FORMAT(//19X,'WATERMASS',16X,'MASS',14X,'SALT',13X,'HEAT',
    1//20X,'SURFACE',6X,3F18.5,//19X,'CALIFORNIA',4X,3F18.5,
    2//16X,'N. PAC. CENTRAL',2X,3F18.5//18X,'INTERMEDIATE',3X,3F18.5,
    3//19X,'SUBARCTIC',5X,3F18.5,//22X,'DEEP',7X,3F18.5,
    4//20X,'UNKNOWN',6X,3F18.5)
C HERE THE WATER COLUMN IS DIVIDED INTO THREE LAYERS - UPPER, MIDDLE, AND DEEP
C AND BOTTOM.
     UPMAS=SFCMAS+CENMAS+CALMAS
     UPSLT=SFCSLT+CENSLT+CALSLT
     UPHT =SFCHT +CENHT+CALHT
     HAFMAS=INTMAS+           SUBMAS+UNKMAS
     HAFSLT=INTSLT+           SUBSLT+UNKSLT
     HAFHT =INTHT+            SUBHT+UNKHT
     DBMAS=DEPMAS
     DBSLT=DEPSLT
     DBHT =DEPHT
     WRITE(8,116)
 116 FORMAT(//13X,'TRANSPORTS BY EACH OF THREE LAYERS')
     WRITE(8,117)UPMAS,UPSLT,UPHT,HAFMAS,HAFSLT,HAFHT,DBMAS,DBSLT,DBHT
 117 FORMAT(//19X,'WATERMASS',16X,'MASS',14X,'SALT',13X,'HEAT',
    1//21X,'UPPER',7X,3F18.5,//20X,'MIDDLE',7X,3F18.5,//14X,'DEEP AND B
    2OTTOM',4X,3F18.5)
     STOT=UPMAS+HAFMAS+DBMAS
     STAT=UPSLT+HAFSLT+DBSLT
     STIT=UPHT+HAFHT+DBHT
     WRITE(8,1001)
     WRITE(8,131) STOT,STAT,STIT
 131 FORMAT(//18X,'SUB TOTAL',6X,3F18.5)
     IF (L .EQ. NGC) GO TO 120
     GO TO 70
 120 WRITE(8,114)
 114 FORMAT('1',12X,'TOTAL TRANSPORTS')
     WRITE (8,109)
```

```
      WRITE (8,110) TSFMAS,TSFSLT,TSFHT,
     *TCLMAS,TCLSLT,TCLHT,TCNMAS,TCNSLT,TCNHT,
     1TINMAS,TINSLT,TINHT,TSBMAS,TSBSLT,TSBHT,TDPMAS,TDPSLT,
     2TDPHT,TUNMAS,TUNSLT,TUNHT
      WRITE (8,116)
      TUPMAS=TCNMAS+TSFMAS+TCLMAS
      TUPSLT=TCNSLT+TSFSLT+TCLSLT
      TUPHT =TCNHT +TSFHT +TCLHT
      TAFMAS=          TINMAS+TSBMAS+TUNMAS
      TAFSLT=          TINSLT+TSBSLT+TUNSLT
      TAFHT =          TINHT +TSBHT +TUNHT
      TDBMAS=TDPMAS
      TDBSLT=TDPSLT
      TDBHT =TDPHT
      WRITE(8,117)TUPMAS,TUPSLT,TUPHT,TAFMAS,TAFSLT,TAFHT,TDBMAS,
     1TDBSLT,TDBHT
      GTOT=TUPMAS+TAFMAS+TDBMAS
      GTAT=TUPSLT+TAFSLT+TDBSLT
      GTIT= TUPHT+TAFHT+TDBHT
      WRITE(8,1001)
      WRITE(8,119) GTOT,GTAT,GTIT
  119 FORMAT(//18X,'GRAND TOTAL      ',3E18.6)
   70 RETURN
      END
```

```
      SUBROUTINE DSTSTA (SATI,ONGI,SATII,ONGII,X2,DIST)
C THIS SUBROUTINE COMPUTES THE HORIZONTAL DISTANCE BETWEEN OCEANOGRAPHIC
C STATIONS.
      IMPLICIT REAL*4 (K)
      REAL*8 A,E
      DATA A/111132.09/,B/566.05/,C/1.20/,D/.002/
      DATA E/111415.13/,F/94.55/,G/.012/
   10 FORMAT (10X,'MEAN LATITUDE = ',F6.2/15X,'DISTANCE = ',F6.2,
     1' KILOMETERS'/)
      CON=2*3.1416/360
      AATI=SATI*CON
      AATII=SATII*CON
      $MERI=A-B*COS(2*AATI)+C*COS(4*AATI)-D*COS(6*AATI)
      PARI=E*COS(AATI)-F*COS(3*AATI)+G*COS(5*AATI)
      $MERII=A-B*COS(2*AATII)+C*COS(4*AATII)-D*COS(6*AATII)
      PARII=E*COS(AATII)-F*COS(3*AATII)+G*COS(5*AATII)
      ALLAT=($MERI+$MERII)/2
      ALLON=(PARI+PARII)/2
      DLAT=SATI-SATII
C
C EAST LONGITUDE CORRECTION
C
      IF((ONGI.LT.0.0).AND.(ONGII.GT.0.0)) GO TO 180
      DLON=ONGI-ONGII
      GO TO 200
  180 DLON=(180.0+ONGI)+(180.0-ONGII)
  200 KLAT=DLAT*ALLAT/1000
      KLONG=DLON*ALLON/1000
      KDIX=SQRT(KLAT**2+KLONG**2)
      DIST=KDIX
      W2=1.458E-4
      PSI=(SATI+SATII)*0.5
      PSJ=(2.*3.14159/360.)*PSI
      SPSI=SIN(PSJ)
      IF(SPSI.LT.0.1) SPSI=0.1
      X2=1./(W2*SPSI*KDIX)
      WRITE (8,10) PSI,KDIX
      RETURN
      END
```

```
      SUBROUTINE SGTSVA (T,S,D,SGT,SV,SVA)
C THIS SUBROUTINE COMPUTES VALUES OF SIGMA-T, SPECIFIC VOLUME ANOMALY, AND
C SPECIFIC VOLUME FOR EACH DEPTH.
      ST=-(((T-3.98)**2)/503.57)*((T+283.)/(T+67.26))
      SO=-0.093+0.8149*S-.000482*S**2+6.8E-6*S**3
      AT=T*(4.7867-.098185*T+.0010843*T**2)*1.E-3
      BT=T*(18.030-.8164*T+.01667*T**2)*1.E-6
      SGT=ST+(SO+.1324)*(1.-AT+BT*(SO-.1324))
      AFST=1./(1.+SGT*1.E-3)
      A=D*AFST*1.E-9
      B=4886./(1.+1.83E-5*D)
      C=227.+28.33*T-.551*T**2+.004*T**3
      E=D*1.E-4
      G=(SO-28.)/10.
      H=147.3-2.72*T+.04*T**2
      U=105.5+9.5*T-.158*T**2
      V=1.5*D**2*T*1.E-8
      W=32.4-.87*T+.02*T**2
      X=4.5-.1*T
      Y=1.8-.06*T
      SV=AFST-A*(B-C+E*U-V-G*(H-E*W)+G**2*(X-E*Y))
      AZ=.972643
      YA=-227.+.01055*D
      YB=.01296*(147.3-.00324*D)
      YC=16.E-7*(4.5-D*.00018)
      AP=AZ-D*AZ*(B+YA-YB+YC)*1.E-9
      SVA=SV-AP
      RETURN
      END
```

TWO SETS OF DATA CARDS - THE FIRST GROUP ARE THE SQUARE AREAS (SQUARE(I)) RELATED TO BOTTOM AREA CONTRIBUTIONS. THE SECOND GROUP OF DATA ARE THE STATION NUMBERS IN PAIRED GROUPS (NPA(I) AND NPB(I)).

```
218.1126.1043.0050.0123.4126.7188.8155.3380.0210.1-73.4243.0157.0056.0107.1762.7
250.0717.8051.7-06.0058.3091.3132.0419.01085.233.3120.0175.0174.3110.0124.0142.0
054.8088.3100.0695.2664.2023.0086.0194.0155.0126.0100.0003.7053.6194.5108.6504.0
541.1

 0102 0203 0304 0405 0506 0607 0708 0809 0910 1011 1112 1213 1314 1415 1516 1617
 1718 1819 1920 2021 2122 2223 2324 2425 2526 2627 2728 2829 2930 3031 3132 3233
 3334 3435 3536 3637 3738 3839 3940 4041 4142 4243 4344 4445 4546 4647 4748 4849
 4950
```

BIBLIOGRAPHY

1. Albrecht, F., "Jahreskarten des Wärme- und Wasserhaushaltes der Ozeane," Ber. Deut. Wetterdienstes, v. 66, Bd. 9, 19 pp., 1960.

2. Angstrom, A. K., "Evaporation and Precipitation at Various Latitudes and the Horizontal Eddy Convectivity of the Atmosphere," Arkiv for Matematik, Astronomi och Fysik, v. 20, 12 pp., 1925.

3. Baker, T. L., Mass, Salt, and Heat Transport Across Seven Latitude Circles in the North Atlantic Ocean: A Descrip- of the General Circulation Based on Geostrophic Calculations from International Geophysical Year and Adjacent Data, Master's Thesis, Naval Postgraduate School, Monterey, California, 1978.

4. Black, J. N., "The Distribution of Solar Radiation Over the Earth's Surface," Archiv Meteorol., Geophys. Bioklimatol., v. 7, no. 2, pp. 165-189, 1956.

5. Brown, R. L., Geostrophic Circulation Off the Coast of Central California, Master's Thesis, Naval Postgraduate School, Monterey, California, 1974.

6. Bryan, K., "Measurements of Meridional Heat Transport by Ocean Currents," Journal of Geophysical Research, v. 67, no. 9, pp. 3403-3414, 1962.

7. Bryan, K., "The Ocean Model," Monthly Weather Review, v. 97, pp. 806-827, 1969.

8. Bryan, K., Manabe, S., and Paconowski, R. C., "A Global Ocean Atmosphere Climate Model. Part II. The Ocean Circulation," Journal of Physical Oceanography, v. 5, pp. 30-46, 1975.

9. Budyko, M. I., The Heat Balance of the Earth's Surface, translated by N. A. Stepanova, 1958, U. S. Department of Commerce, Washington, D.C., 259 pp., 1956.

10. Cummings, W. J., "A Description of the General Circulation in the North Atlantic Ocean Based on Mass Transport Values Derived from IGY (1957-1958) Temperature and Salinity Data, Master's Thesis, Naval Postgraduate School, Monterey, California, 1977.

11. Defant, A., "Die absolute Topographie des physikalischen Meeresniveuas und der Druckflächen, sowie die Wasserbewegungen im Atlantischen Ozean," Deutsche Alantische Exped. Meteor. 1925-1927, Wiss. Erg., Bd. VI, 2 Teil, 5 Lief, p. 191-260, 1941.

12. Defant, A., Physical Oceanography, v. 1, Pergamon Press, 1961.

13. Dietrich, G., "Die dynamische Bezugsfläche, ein Gegenwartsproblem der dynamischen Ozeanographie," Ann. d. Hydrogr. u. Mar. Meteor., Bd. 65, pp. 506-519, 1937.

14. Emig, M., "Heat Transport by Ocean Currents," Journal of Geophysical Research, v. 72, no. 10, pp. 2519-2529, 1967.

15. Fomin, L. M., The Dynamic Method in Oceanography, p. 117-148, Elsevier Publishing Company, 1964.

16. Gerald, C. F., Applied Numerical Analysis, 2d ed., Addison-Wesley, 1978.

17. Greeson, T. D., Mass, Salt, and Heat Transport Across 40°N Latitude in the Atlantic Ocean Based on IGY Data and Dynamic Height Calculations, Master's Thesis, Naval Postgraduate School, Monterey, California, 1974.

18. Handbook of Oceanographic Tables, SP-68, United States Naval Oceanographic Office, 1966.

19. Hidaka, K., "Depth of Motionless Layer as Inferred from the Distribution of Salinity in the Ocean," Trans. Am. Geophys. Union, v. 30, no. 3, 1940.

20. Houghton, H., "On the Annual Heat Balance of the Northern Hemisphere," Journal of Meteorology, v. 11, no. 1, pp. 1-9, 1954.

21. Ingmanson, D. E. and W. J. Wallace, Oceanology: An Introduction, p. 163, Wadsworth, 1973.

22. Iselin, C. O'D., "A Study of the Circulation of the Western North Atlantic," Papers in Physical Oceanography and Meteorology, v. 4, no. 4, 101 pp., 1936.

23. Jacobs, W. C., "The Energy Exchange Between Sea and Atmosphere and Some of its Consequences," Bulletin of the Scripps Institution of Oceanography, v. 6, pp. 27-122, 1951.

24. Jung, G. H., "Note on the Meridional Transport of Energy by the Oceans," Journal of Marine Research, v. XI, no. 2, pp. 139-146, 1952.

25. Jung, G. H., Heat Transport in the North Atlantic Ocean, Ph.D. Thesis, The A. & M. College of Texas, College Station, Texas, 1955.

26. Jung, G. H., Energy Transport by Air and Sea, The Dynamic North, Book I, OPNAV P03-8, Chief of Naval Operations, Technical Assistant for Polar Projects, pp. 1-19, 1956.

27. Kimball, H. H., "Radiation Charts," Monthly Weather Review, v. 56, 1928.

28. Manabe, S., "The Atmospheric Circulation and the Effect of Heat Transfer by Ocean Currents," Monthly Weather Review, v. 97, pp. 775-805, 1969.

29. Manabe, S., Bryan, K., and Spelman, M. J., "A Global Ocean-Atmosphere Climate Model. Part I. The Atmospheric Circulation," Journal of Physical Oceanography, v. 5, pp. 3-29, 1975.

30. Mason, J. R., Mass, Salt, and Heat Transport Across Four Latitude Circles in the South Atlantic Ocean, Master's Thesis, Naval Postgraduate School, Monterey, California, 1978.

31. Maury, M. F., The Physical Geography of the Sea, 6th ed., Harper, 1856.

32. Neumann, G. and Pierson, W. J., Jr., Principles of Physical Oceanography, Prentice-Hall, 1966.

33. North Pacific Ocean Bathymetric Atlas, United States Navy Oceanographic Office, 1973.

34. Oort, A. H. and Vonder Haar, T. H., "On the Observed Annual Cycle in the Ocean-Atmosphere Heat Balance Over the Northern Hemisphere," Journal of Physical Oceanography, v. 6, no. 6, pp. 781-800, 1976.

35. Parr, A., "Analysis of Current Profiles by a Study of Pycnomeric Distortion and Identifying Properties," Journal of Marine Research, v. 4, 1938.

36. Patullo, J. G., The Seasonal Heat Budget of the Oceans, Ph.D. Dissertation, University of California, 1957.

37. Perry, A. H. and Walker, J. M., The Ocean-Atmosphere System, Longman, 160 pp., 1977.

38. Rossby, C. G., "Dynamics of Steady Ocean Currents in the Light of Experimental Fluid Mechanics," Papers in Physical Oceanography and Meteorology, v. 5, no. 1, 43 pp., 1936.

39. Sellers, W. D., Physical Climatology, University of Chicago Press, 1965.

40. Sherfesee, L., Mass, Salt, and Heat Transport in the South Pacific, Master's Thesis, Naval Postgraduate School, Monterey, California, 1978.

41. Stommel, H., "On the Determination of the Depth of No Meridional Motion," Deep-Sea Research, v. 3, p. 273-278, 1956.

42. Stommel, H. and Schott, F., "The Beta Spiral and the Determination of the Absolute Velocity Field from Hydrographic Station Data," Deep-Sea Research, v. 24, p. 325-329, 1977.

43. Sverdrup, H. U., Johnson, M. W., and Fleming, R. H., The Oceans: Their Physics, Chemistry, and General Biology, Prentice-Hall, 1942.

44. Sverdrup, H. U., Oceanography, Handbuch der Physik, 48(28), Springer Verlag, Berlin, pp. 608-670, 1957.

45. Tabata, S., "Variability of Oceanographic Conditions of Ocean Station P in the Northeast Pacific Ocean," Trans. Roy. Soc. Canada, v. 3, series IV, section 3, pp. 367-418, 1965.

46. Tabata, S., "The General Circulation of the Pacific Ocean and a Brief Account of the Oceanographic Structure of the North Pacific Ocean, Part I - Circulation and Volume Transports," Atmosphere, v. 13, no. 4, pp. 133-168, 1975.

47. Tabata, S., "The General Circulation of the Pacific Ocean and a Brief Account of the Oceanographic Structure of the North Pacific Ocean, Part II - Thermal Regime and Influence on the Climate," Atmosphere, v. 14, no. 1, pp. 1-27, 1976.

48. Users Manual, W. R. Church Computer Center, Naval Postgraduate School, Monterey, California, 1970.

49. Vonder Haar, T. H. and Oort, A. H., "New Estimate of Annual Poleward Energy Transport by Northern Hemisphere Oceans," Journal of Physical Oceanography, v. 3, no. 2, pp. 169-172, 1973.

50. Williams, J., An Introduction to the Marine Sciences, Oceanography, p. 122, Little, Brown and Company, 1962.

51. Wyrtki, K., "The Average Annual Heat Balance of the North Pacific Ocean and its Relation to Ocean Circulation," Journal of Geophysical Research, v. 70, no. 18, pp. 4547-4559, 1965.

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